

## **CHAPTER 3**

### **EXISTING CONDITIONS**

#### **3.1 STUDY AREA**

The SEIS study area generally encompasses the Little Rocky Mountains. The study area for each environmental resource varies depending upon the extent of potential impacts to that resource. For example, impacts to soils and vegetation are generally confined to the area of direct disturbance; while impacts to economic, social or visual resources may extend many miles beyond the project area.

This chapter describes the existing resource conditions at or near the Zortman and Landusky Mines that would be affected by the alternatives. Since the purpose of the analysis is to consider the effectiveness of alternatives to reclaim existing disturbance, this chapter includes both a description of the affected environment and a description of the existing impacts that have been created by the mining activity. The chapter focuses on resource conditions that are relevant to reclamation by describing existing impacts which could be mitigated by the reclamation alternatives. The cumulative impacts from past mining actions are included in the description of existing conditions. Additional information on the affected environment around the mines can be found in Chapter 3 of the 1996 FEIS.



## **3.2 GEOLOGY and GEOTECHNICAL CONDITIONS**

Geology has influenced the pattern of patented and Federal lands in the Little Rocky Mountains. The majority of the mine pits are located on private lands since they define the most valuable mineralized zones. The unpatented Federal lands are, conversely, the nonmineralized areas that were used for location of the mine facilities such as waste rock dumps, heaps, ponds and water treatment plants. This section describes the geology of the Little Rocky Mountain area in general with specific detail focused on the mine area without regard to land ownership.

Since completion of the FEIS in 1996, a detailed geology report was completed by ZMI. The “Geologic Evaluation of the Zortman and Landusky Mine Sites and Surrounding Little Rocky Mountains” (1996) includes detailed geologic maps and associated cross sections illustrating relationships between the hydrostratigraphic units, structures, and associated mine facilities. While this study was not available for the FEIS, the location of shears and underground workings and their impact on groundwater flow was well known. The Groundwater Study (WMCi 1998) incorporated results of the ZMI Geologic Evaluation.

### **3.2.1 Geology and Topography**

This section describes the regional geologic setting of the Little Rocky Mountains, the mineral associations and occurrences within the study area, and the structural forces which have played a major role in both the shape of the mountains and the locations of ore deposits. The Zortman and Landusky Mines are within the Little Rocky Mountains of northcentral Montana. Gold mining has been conducted in the Little Rocky Mountains for over 100 years. As a result, an extensive database of information exists concerning the geology of the mountains and the ore deposits contained therein.

The Little Rocky Mountains are within the Northern Great Plains geographic region, which is distinguished by rolling prairies dissected by intermittent drainages. Small mountain ranges that rise abruptly in the region are often called “island mountain ranges” because they rise above the relatively flat plains like islands in an ocean. Other island mountain ranges in this region include the North and South Moccasin Mountains, the Bears Paw Mountains, the Sweet Grass Hills, and the Judith Mountains.

The Little Rocky Mountains rise in dramatic relief more than 2500 feet above the surrounding plains. Old Scraggy Peak, located about 1.5 miles east of the Zortman Mine, is the highest point in the Little Rocky Mountains at approximately 5700 feet amsl. In contrast, Goslin Flats south of the town of Zortman is at an elevation of approximately 3800 feet amsl. The surrounding plains are significantly lower. Fort Peck Lake, 50 miles east of the Little Rocky Mountains, sits at about 2300 feet amsl. The topography within the Little Rocky Mountains is rugged, marked by high outcrops of erosion resistant rocks and steep, V-shaped valleys with little accumulation of soil or alluvial materials.

The plains north of the Little Rocky Mountains slope gradually into the Milk River bottom which occupies the pre-glacial channel of the Missouri. To the south, the surface water drainage has carved steep narrow

channels into a badlands-type topography. Southwest and south of the Little Rocky Mountains, the topography is strongly influenced by the post-glacial channel of the Missouri River. Intermittent streams and coulees coalesce to form tributaries of the Missouri River, and the topography becomes more broken as the drainages easily incise through the relatively soft sedimentary rocks which make up most of this region.

The topography in the mining area has been altered by excavation of the open pits and construction of the waste rock dumps and leach pads. A three dimensional simulation of the topography around the mines is shown in Figures E-1 and E-8, in Appendix E of the Draft SEIS.

## **Historical Geology**

The Little Rocky Mountains are found in a region exhibiting geologic extremes in rock types, history of rock formation and emplacement, and age of materials. The regional geology ranges from upland prairie which was glaciated as recently as 10,000 years ago, to the nearly 3 billion year old rocks exposed in mountainous areas (BLM 1992).

The oldest rocks in the region are Precambrian Era (greater than 650 million years old) metamorphic gneisses and schists. Metamorphic rocks are those which have been altered in texture or composition due to temperature, pressure, and/or chemical processes. These very old rocks outcrop only in some of the mountain ranges, including the Little Rocky Mountains, where magma upwelling from below the earth's surface has pushed older rocks up through younger strata.

Thick sequences of Paleozoic Era (570 to 240 million years ago) sedimentary rocks are found in the mountain ranges and on the plains. Sedimentary rocks are those which have formed by the accumulation of sediments or minerals precipitated from water. These rocks are predominantly limestones and dolomites which typically formed in marine environments, but sandstones and shales also occur. These are the rock types which usually do not contain much gold or precious metals, but they are still important because they can be used in construction or as reclamation materials. Limestones, dolomites, and other “calcareous” rocks (those containing significant amounts of calcium carbonate) are very useful because they can neutralize or buffer water which has been acidified by mine operations. These rocks are very resistant to erosion and form some of the spectacular cliffs in the mountain ranges; they also contain some important cave formations, such as Azure Cave on the south side of the Little Rocky Mountains.

Mesozoic Era (240 to 66 million years ago) rocks comprise another sedimentary sequence in this region. Sedimentary rocks from the Jurassic period of the Mesozoic are typically calcareous sandstones and shales. Gypsum and coal have been mined from Jurassic sediments in the region. Cretaceous period rocks are typically sedimentary, with the different rock formations representing episodes of advance and retreat of a large inland sea which covered much of North America at that time. These sediments include sandstones, shales, and limestones. Coal and bentonite have been mined from various Cretaceous formations. Thick carbonaceous shales from the Cretaceous also provide for oil and gas development in the region.

The geology and topography of the region have been determined by two activities during the Cenozoic Era (66 million years ago to the present). Extensive igneous activity during the Tertiary period of the Cenozoic Era resulted in the formation of island mountain ranges described earlier. This igneous activity in Montana appears to follow the structural controls of a regional feature known as the Great Falls Tectonic Zone. Described by O'Neil and Lopez (1985), the Great Falls Tectonic Zone is a belt of northeast-trending geologic features that can be traced from the Idaho Batholith in northcentral Idaho and western Montana, across the overthrust belt structures of southwestern Montana, through central Montana and into southwesternmost Saskatchewan, Canada. Geologists believe the Great Falls Tectonic Zone controlled the intrusion patterns and orientation of late Cretaceous to early Tertiary igneous intrusions and dike swarms, including those of the Little Rocky Mountains and other area mountain systems.

More recently, during the Quaternary period of the Cenozoic Era, massive glaciers advanced and retreated over much of the region leaving glacial deposits and debris in most of the area north of the Missouri River. Erosive forces have continued to alter the region's landscape, removing weathered bedrock from mountainous areas and depositing it as unconsolidated deposits in valleys and plains.

The rock types are younger with increasing distance from the Precambrian rocks near the center of the dome. Most of the Paleozoic sedimentary rocks in this area were created in a marine environment. These sedimentary rocks are more resistant to erosion and may form prominent buttes, ridges, and cliffs. The deepest (and oldest) of the sedimentary formations is the Flathead sandstone. It is overlain by approximately 3,000 feet of limestones and dolomites, with lesser amounts of shale, sandstone, and conglomerate. The top sequence of Paleozoic rocks consists of Madison Group limestones, which are found around the margins of all the island mountains in Montana.

The Mesozoic rocks in the area consist primarily of shales, with lesser amounts of sandstones, conglomerates, and limestones. In general, the Mesozoic rocks represent terrestrial and near-marine environments, when sediments from earlier ages were eroded and redeposited in valley floors, river and stream beds, and outwash plains. These sediments are found as bedrock at or near the surface in the areas around the Little Rocky Mountains. A fairly complete stratigraphic section, from Pre-Cambrian metamorphic rocks to Cretaceous (Bearpaw Shale), is exposed along the flanks of the mountains.

Younger rocks of the current Cenozoic Era are igneous intrusives. The igneous rocks in this area occur as syenite porphyries. Emplacement of the Cenozoic intrusive rocks resulted in the formation of the Little Rocky Mountains, as described at the beginning of this section. In addition, intrusion of the igneous rocks mobilized and deposited elements such as gold in sufficient concentrations to make mining them economic.

Sulfide mineralization is associated with gold deposits. The sulfide mineral pyrite occurs along fractures in association with the gold mineralization. Upon mining, the rock breaks preferentially along fractures exposing not only the gold to leaching, but the pyrite minerals to weathering. Thus, the same mechanism that makes leaching of the gold possible without crushing the ore also exposes more of the sulfide minerals to weathering than would otherwise occur if they were evenly distributed throughout the rock.

## **Economic Geology**

The reason gold and other precious metals have been found in the Little Rocky Mountains is directly related to the solidification history of the igneous porphyry rocks. After upwelling and emplacement of the igneous magmas, a hydrothermal system dominated by low pH, low salinity waters heated by the igneous magma developed (Russell 1991a). This hot, acidic water caused widespread alteration in rocks of the Zortman/Landusky Mining District. Hydrothermal flow of the heated waters was channeled along the existing structural trends of the intrusive rocks. Gold, silver, and associated minerals such as pyrite were dissolved in the hot water because of the low pH. Changes in pressure, fluid chemistry, or reductions in temperature could cause the pH of the water to increase, resulting in precipitation of gold and minerals. The minerals were typically distributed within the structural channels, often in dikes or veins of quartz, or along fracture zones of crushed and broken rock called breccias. Metal sulfide minerals and gold were also disseminated throughout the rocks. Some of the existing environmental impacts at the mines result from what is essentially a reversal of this process. As the minerals in waste rock and ore are exposed to air and water during mining, the sulfides react to form sulfuric acid and lower the pH of the water. This acidification process partially dissolves minerals back into solution. A more detailed discussion of this process can be found in the 1996 FEIS and in Section 3.3.2 of this document.

Vein lode deposits of gold were first discovered in the Little Rocky Mountains in 1892. The vein deposits are typically the most heavily enriched in gold or other precious metals; hence, they are the most valuable deposits. They were also relatively easy for the lone prospector or small operation to mine, because mining only required that the vein be followed.

Natural erosional forces also created new, localized areas of concentrated gold. Rain, snow, and seasonal weathering of the mountains and mineralized zones break up rock in the higher elevations and carry it down into stream channels, valleys and basins. Deposits of eroded material from mineralized zones are called placers. Placer deposits were often the first and best indicators to the old prospectors of the last century that ore zones could be found in the higher areas of mountain regions. This is the case for the Little Rocky Mountains. The first placer deposits were developed in Alder Gulch in 1884, while the first lode claims were patented in 1892.

Some very rich “bonanza-type” gold ore was historically produced in the Little Rocky Mountains from the vein deposits described above; however, most modern production has come from relatively low grade ore (typically ranging from 0.022 to 0.028 ounces per ton, although even lower grades have been mined at the Landusky Mine). The mineral deposits occur in the altered syenite porphyries, and are associated with high-angle faults or fractures, the channels along which mineralized hydrothermal waters had access. At the Zortman Mine, gold mineralization has been concentrated at the intersections of north and northwest-trending mineralized fractures, and occurs as finely disseminated particles. The richest ore bodies have been within the porphyry-hosted “breccia” dikes, the rock type resulting from crushing and grinding along a fault or fracture. Sulfide mineralization in the O.K. pit area, a mineralized breccia 15 to 100 feet wide emplaced along a northwest-trending fracture, was continuous from the mountain top to an

average depth of 500 feet. In the Landusky Mine area, economically viable gold deposits are found where the number and/or extent of fractures is greatest. These systems at the Landusky Mine parallel the inferred southwest to northeast trend of the Great Falls Tectonic Zone.

Both the oxide and sulfide portions of the ore bodies were excavated at the mines. Oxidation of the ore generally has occurred nearest the surface, and along fractures which have transported surface water and shallow groundwater deeper in the ore zones. Although gold and silver are easier to separate from oxidized ores using cyanide heap leach processes, the nature of the ore bodies in most cases resulted in a mixture of oxide and sulfide ore being mined. This generally resulted in lowered leach recoveries for ores containing larger amounts of sulfide as the precious metals are more tightly bound in the geochemical matrix of the mineralization. Iron sulfides are the most abundant species at the Zortman and Landusky Mines, including minerals such as pyrite, marcasite, arsenopyrite, and others.

Approximately 20 million tons of gold and silver bearing ore were mined at the Zortman Mine during the years 1979 to 1994, and about 125 million tons of ore were mined at the Landusky Mine during the same years. Gold and silver production during the 1979 to 1994 period was approximately 1.7 million troy ounces of gold and 6.6 million troy ounces of silver (FEIS, Table 3.1-1).

Additional resources of gold and silver exist within the Little Rocky Mountains. Other reasonably foreseeable deposits, including one in Pony Gulch which has been estimated to contain about 2 million tons of ore. The deeper sulfide ore zones proposed to be mined by ZMI in the expansion plan contained at least another 1 million ounces of gold resources. Lower grade resources occur in the area but are not economically feasible to mine using current technology. Both the proven and estimated reserves of the mineral development potential are classified as “high” for gold and silver in the Little Rocky Mountains (BLM 1992). With the decline in gold prices since 1992 these deposits are sub-economic.

### **Shear Zones**

The Zortman mining area has two major structural zones. The Alabama shear is centered on the South Alabama pit and the Ruby shear zone is centered on the O.K./Ruby pits. These shear zones strike N10°-30°W and dip 75-85° to the west. Other less continuous structures strike about N10°E with near vertical dips. The North Ruby shear is located in the central portion of the Ruby highwall. Major structures are supported by numerous parallel, secondary cross structures. Mineralization is generally concentrated at the intersections of these structures with numerous parallel N70-80°E cross structures (WMCI, p. 147). North-northwesterly shear zones identified in the Zortman mining area include:

- Alabama shear in the South Alabama pit;
- North shear and the Ruby shear in the O.K./Ruby pits;
- Ruby-Ross shear in the O.K. pit;
- O.K. Shear, which may have a more northerly strike and appears to offset the Ruby-Ross shear in the O.K. pit;

- Mint shear, located to the east of the O.K. pit; and
- An unnamed fault, located between the O.K. pit and the North Alabama pit.

Both northeast and northwest faulting are present in the Landusky Mine area. Northeast striking structures exert the greatest control on mineralization, evidenced by the northeast elongation of the Landusky area orebodies. However, intersections with smaller cross faults are more strongly mineralized due to enhancement of fracturing at these locations. Cross faults in the Landusky Mine area have been mapped with N70-80°E orientations. A prominent northwesterly-striking fault, the Narrows fault, transects the Landusky Mine and is unmineralized, as are subparallel associated structures (WMCI, p. 148). Four northeast striking normal faults localize the mineralization in the Landusky Mine orebodies (See Also Figures 3.3-6 and 3.3-7 in Section 3.3).

*Gold Bug Shear:* The Gold Bug shear strikes N40-50°E and dips 65-70°NW. Along the southeast half of the Queen Rose pit, this fault juxtaposes Precambrian felsic gneisses in the hanging wall with mainly syenite porphyry in the footwall. A zone of breccia up to 200 feet thick is present in the hanging wall at the fault contact. A southwestern extension of this fault, offset to the south by the Narrows fault, continues on a similar strike in the Niseka/Gold Bug pit. In this area, the fault cuts syenite porphyry.

*Niseka Shear:* The Niseka shear strikes N50°E and dips about 70°NW. Along the southeast side of the August pit, this fault cuts syenite porphyry, except at its northeast end where it cuts a roof pendant of Emerson Shale.

*August Shear:* The August shear strikes approximately N45°E and dips 75°NW. This fault cuts syenite porphyry. Several thin, discontinuous trachyte porphyry dikes occur along the fault.

*Suprise Shear:* The Suprise shear strikes N45°E and dips 70-80°SE. Along the northwest half of the Queen Rose pit, this fault cuts predominantly syenite porphyry, except at its southwest end, where it cuts a roof pendant of Emerson shale and Bighorn dolomite. It is progressively offset in this area, in a left lateral sense, by a series of faults subparallel to the Narrows fault in the Little Ben pit. The hanging wall and footwall consist of syenite porphyry, with small pendants of Bighorn dolomite and a few thin breccia dikes.

Northwest striking faults include the Narrows fault and subparallel adjacent faults, and small cross faults of the northeast faults. The Narrows fault strikes N10-20°W and dips approximately 80°E. It is believed to have a left-lateral component of offset of as much as 1,200 feet, based upon correlation of the Suprise Shear on opposite sides of the Narrows fault. The Narrows fault is unmineralized. It offsets the mineralized structures, indicating that its displacement took place subsequent to the hydrothermal mineralizing event (WMCI, p. 149).

The Little Rocky Mountains were originally interpreted to be igneous intrusions with flat bases and domed roofs (laccoliths) which arch the overlying sediments according to the shape of the igneous dome. However, Russell (1991b) cites field indications that the intrusions were not emplaced parallel to the

sedimentary formations which were already present. In addition, he notes that active mining and exploration drilling in the Zortman and Landusky pits has failed to reach a floor or bottom to the intrusion. This evidence suggests the porphyries were not intruded as laccoliths but as stocks, a type of igneous intrusion which is relatively small in size and which cuts across formation boundaries. The structure of the intrusion displays features of both a laccolith (mushroom shaped with a relatively flat floor) and a stock (the intrusion is small and cuts across some lithologic boundaries).

The major controls on the geologic structure of the area are steeply dipping, north-northwest trending fractures. Most faults between the intrusions and surrounding sedimentary rocks are steeply dipping (i.e. more vertical than horizontal) with a relatively large component of up or down movement. Most faults within intrusions are described as shears, suggesting more lateral than vertical movement along the fractures. As noted previously, these fault structures had a major influence on localization of mineral deposits. Faults, joints, and fractures can also play an important role for groundwater transport in the Little Rocky Mountains, particularly in controlling the direction of flow.

Fractures and structural features of the central portion of the Little Rocky Mountains are where the Zortman and Landusky Mine pits are located. It is easy to see that most mineralized fractures (those containing precious metals) trend north-northwest in the vicinity of the Zortman Mine, and north-northeast in the vicinity of the Landusky Mine.

### **Reclamation Resources**

Clay-rich shale formations have been used for mining construction, operations, and reclamation activities conducted at the mines. There are three existing sources of clay material located on private lands that have been used by the mines. A small clay pit is located a quarter mile west of Zortman in Alder Gulch. A larger source is located seven miles south of Zortman along U.S. Highway 191. The clay source for the Landusky Mine is 2 miles west of the mine along State Highway 66. These clay deposits are from a marine shale of Cretaceous age. When compacted, the clay forms low permeability layers that restrict water infiltration. While these deposits do not have the commercial application of bentonite, they are valuable for use in various mining operations, particularly those where barriers are needed to prevent the migration of leachate (i.e. leach pad liners) or to prevent infiltration of surface water (i.e. reclamation covers).

Limestone is used in the construction industry for producing lime, in mining and industrial chemical processes to control pH, and in agriculture as a soil conditioner. There are vast limestone resources in central and western Montana, much of it within the Madison Group of Mississippian-age sedimentary formations. The limestone mining that has occurred in the vicinity of the Little Rocky Mountains has typically been restricted to small, isolated quarries.

Limestone is very hard and resistant to processes of physical weathering such as freezing and thawing, or wind erosion. However, limestone is soluble in water and its dissolution provides conduits for groundwater

flow, often through larger openings such as fractures and joints. In fact, the Madison Group of limestones serves as the major deep aquifer surrounding and underlying the Little Rocky Mountains.

Limestone has been and may continue to be used in reclamation activities for both the Landusky and Zortman Mines, in the construction of drains or other facilities where material with a high net neutralization potential is needed. Large outcrops of limestone which are easily recognizable as prominent cliffs and bluffs occur near the Zortman and Landusky Mines. The limestones which could be used in mining and mine reclamation activities would come from the Devonian-age Jefferson Formation or Mississippian-age Madison Formation.

The King Creek quarry site is located about 1/4 mile northwest of the Landusky Mine's Queen Rose pit in the NE $\frac{1}{4}$  of Section 15, Township 25N, Range 24E. The King Creek quarry is on private land and was previously mined by different parties. ZMI was permitted to mine about 50,000 tons of limestone from this site in 1993 for the King Creek cleanup project and for other mine operational uses. Also on the Landusky side, similar material could be mined at the Montana Gulch quarry, located in the NW $\frac{1}{4}$ SW $\frac{1}{4}$  of Section 22, Township 25N., Range 24E. This site is on BLM-administered lands and may be used as a source during the reclamation.

Limestone for use in Zortman Mine facilities and reclamation could be mined at a quarry known as "LS-1" in the NE $\frac{1}{4}$ SW $\frac{1}{4}$  of Section 6, Township 5N, Range 25E, approximately one-half mile north of the Ross pit. ZMI estimated this source contains approximately one million tons of limestone. Limestone is also available at the site known as "LS-2" in Section 17, Township 25 N, Range 25E.

Sand and gravel pits are found on private and public land throughout the foothills adjacent to the steep rise of the mountains. Ready sources of these materials are available in the glacial and alluvial deposits which cover the bedrock to depths of 50 to 100 feet at the base of the mountains for several miles in all directions. These deposits can be useful in construction of road base, in drains, and as capillary breaks in reclamation covers.

### **3.2.2 Geotechnical Conditions**

#### **Seismic Conditions**

The Little Rocky Mountains are an area of low earthquake hazard. Based on the probabilistic earthquake acceleration and velocity map for the United States (Algermissen et al. 1990), the Little Rocky Mountains are located within the lowest risk area designated. There are no known unstable areas, although landslides/rockslides are always a potential hazard where steep slopes and ridges are common, such as in the interior of the mountains. Although faults are present as previously described, none are believed to be currently active, or to have been active in recent times.

## **Subsidence**

Underground (stope) mining was prevalent in the Little Rocky Mountains before ZMI started open pit mining. As a result, a relatively large network of underground shafts and tunnels exists. The hazard presented by the underground mine workings is that there may be insufficient ground support resulting in surface slumps similar to those commonly associated with sinkhole formations.

## **Heap Dike Stability**

In July 2000, two reports (Womack 2000a and 2000b) were completed on the stability of the leach pad dikes at both mines to determine the risk of failure. The reports concluded that all the dikes are stable and would remain stable into the future. However, the addition of any more rock behind the dikes might result in failure of the structures. The report noted that the Z89 dike has the greatest potential for failure. The existing dikes meet minimum safety requirements and do not need additional support from reconstruction or buttressing if recontouring and reclamation covers decrease infiltration of precipitation.

## **Heap and Dump Slope Stability**

The same reports concluded that engineering safety factors at all of the heaps and dumps are within the limits of construction design criteria for the facilities. The engineered design of these facilities assumes that the water level in the pore space of the rock does not exceed the top of the dike/liner interface. The greatest risk of failure for these facilities comes from infiltrated precipitation rising above that level. The report pointed out that the sooner the facilities are capped and reclaimed to reduce infiltration of precipitation the more stable they would be in the long term.

## **Mine Pit Wall Stability**

The stability of the pit highwalls has not been evaluated beyond the original mine design criteria. Those criteria analyzed short-term stability relative primarily to mine operation and safety considerations. Since the end of mining in 1996 there have been no mass failures, slumping or settling observed in the highwalls. Over time, weathering and other natural forces tend to reduce the stability of the pit highwalls, making them more susceptible to mass failure, most probably in the form of rock slides. To protect public safety, at least some of the pit highwall areas would be fenced and signed to limit public access to potentially unsafe areas.

### **3.3 WATER RESOURCES and GEOCHEMISTRY**

#### **3.3.1 Description of Supplemental Studies and Information**

This section presents information on the water resources and geochemistry of the Zortman and Landusky Mines as a supplement to that in the 1996 FEIS. The FEIS documented water resources and geochemistry changes that occurred over the 17 years from 1979 to 1995. This SEIS provides similar information for the years 1996 to 2001. The principal sources of supplemental information are:

- Public Health Assessment for Kings Creek (a/k/a Fort Belknap Indian Reservation/ Zortman Mining Incorporated (ATSDR 1998). Results of the fourth ATSDR public health study to determine if the Zortman and Landusky Mines were posing a health hazard to the people of the reservation by releasing toxic substances into the environment, especially drinking water sources.
- Zortman/Landusky Project Draft Summary Report for the Groundwater Investigation (WMCi 1998). Results of the Consent Decree mandated groundwater study. Presented in three volumes.
- Zortman and Landusky Mines, Comparison of the Final Environmental Impact Statement, ATSDR Public Health Assessment, and Groundwater Study (Gallagher 1999). An evaluation and comparison of the results of the ATSDR study and the WMCi Groundwater Study with results from the FEIS. This report incorporated the new groundwater information into the existing environmental analysis results, verified whether the findings of the FEIS regarding groundwater characterization were accurate, and identified groundwater data to be obtained or assumed in order to make an informed decision regarding reclamation.
- Zortman Mine Water Balance and Chemical Mass Loading (Spectrum 2000a). This report presents the results of a surface and ground water balance and mass loading evaluation for the mine site. The products of this investigation were used to evaluate and prioritize mine reclamation options.
- Landusky Mine Water Balance and Chemical Mass Loading (Spectrum 2000b). See above description for the Zortman Mine.
- Goslin Flats Land Application Disposal (LAD) Expansion Assessment and 2000-2001 Plan of Operations (HSI and Spectrum 2000). This document describes the information and rationale for expansion of the 364-acre Goslin Flats LAD area to manage leach pad water treatment and disposal for the years 2000 and 2001.
- Field Reconnaissance and Laboratory Testing Program for the Zortman/Landusky Reclamation Project (Robertson 1999, 2000b). A report documenting the results of geochemical testing of 212 samples. Non-acid generating (NAG) material, acid generating materials, and contaminant sources

were identified. A map showing the distribution of various reclamation materials was also produced. This information is important in designing reclamation options for pits and rock dumps, and for reclamation covers, all significant factors in the protection of groundwater quality at the mines.

- Cover Performance Modeling, Zortman and Landusky Mine Sites (Robertson 2000c). The results of the cover modeling are important in designing reclamation options for pits, rock dumps and leach pads. This information also assisted in prediction of the relative volumes of water requiring management and the impacts of each alternative to water quality.
- Report on the Landusky Mine's Hydrologic Impact to King Creek and Swift Gulch (Spectrum 2000c), and the Report Addendum (Spectrum 2001c). These reports quantify potential losses in surface water flow volume to the drainages north of the Landusky Mine. Calculations are based on pre-mining conditions and on the altered surface and ground water divides created by mining.

A more detailed discussion of the listed reports' contents can be found in Gallagher (1999) and HSI and Gallagher (2001). In addition, unpublished groundwater monitoring data collected at both mines from 1996 to 2001 were used in this supplemental assessment. These data were collected by ZMI and its contractors, and the DEQ and its contractors, and are available from the Helena office of the DEQ.

### **3.3.2 Geochemistry/Acid Rock Drainage**

#### **General Geochemical Processes**

Precious metal mining sites have the potential to degrade water quality through two general types of geochemical processes: (1) generation of alkaline seepage – cyanide-related processes; and (2) production of acid water from acid rock drainage (ARD). These processes were described in detail in the 1996 FEIS (pp. 3-16 to 3-18) and are summarized below.

Alkaline seepage is characterized by high pH values (above 7 s.u. and typically around 9 s.u.) and potentially elevated concentrations of cyanide, nitrogen and sulfur compounds, as well as metals such as iron, arsenic, molybdenum, copper and selenium. This water is related to the gold leaching process; therefore it originates in the leach pads or process circuit. All leach pad waters are treated at the land application disposal (LAD) area. If the leach pad water is acidic it is first sent to the water treatment plant to remove the acidity.

Acid rock drainage, also called acid mine drainage, is water characterized by low pH values (typically between 2 and 5 s.u.) and elevated concentrations of sulfate, aluminum, iron, copper, manganese, nickel, zinc, etc. This water results from the oxidation of iron sulfide minerals (such as pyrite) and the subsequent dissolution of other minerals by the acidic water.

## **Existing Conditions**

At the initiation of open pit mining at the Zortman and Landusky Mines in 1979, it was determined that ARD would not be a significant issue (DSL 1979b, pp. 75-76). However, as mining progressed, analyses showed that geological materials at both mines were generating acidic waters. Data from the early 1990s indicated that most of the major southern flowing drainages were showing some degree of impact from mining-related activities. Once detected, the monitoring program was augmented to determine the scope of the impact. The results of that program have shown increasing levels of acidity and metals related to ARD development.

In accordance with requirements of the BLM and DEQ, and as part of the Consent Decree, capture systems and water treatment facilities were built at both mines in the mid-1990s. ARD is collected and pumped to the water treatment plants where acidity and metals are removed by lime addition. Treated water from the Zortman Mine is discharged to Ruby Gulch. Treated water from the Landusky Mine is discharged to Montana Gulch. The detailed water balance and chemical mass loading evaluations conducted for both mines demonstrate that the seepage collection systems are capturing 97% of the total sulfate load and 96% of the total metals load at the Zortman Mine; and 90% of the total sulfate load and 98% of the total metals load at the Landusky Mine (Spectrum 2000a and 2000b). Descriptions of the existing water quality conditions in each drainage near the mines are provided in Sections 3.3.6 and 3.3.7.

## **Geochemical Testing**

Rock types include Tertiary syenite porphyry and monzonite, Precambrian amphibolite and felsic gneiss, Paleozoic sedimentary rocks, and quartzites and breccias. A detailed discussion of rock types is found in the FEIS (pp. 3-18 to 3-20).

A large number of geochemical tests were conducted as part of the 1996 FEIS analyses. Over two thousand samples of ore, spent ore, waste rock and other unmineralized local rock types from both mines were tested. Test methods included total sulfur, paste pH, and acid base accounting (ABA), as well as, kinetic tests called humidity cells. The purpose of the testing was to determine the acid generating or acid neutralizing characteristics of different ore and waste rock types. The results and interpretation of these tests are presented in the FEIS (pp. 3-20 to 3-46).

Kinetic tests are designed to assess the acid generating potential of a material by accelerating the effects of weathering in the lab. This is done by leaching moist, hot air through the material in a cell and analyzing the leachate collected from the cell. Much of the kinetic testing completed for the FEIS was done to predict the geochemical characteristics of the material that would have been mined if the mine expansion had been carried out. The tests are designed to simulate weathering and are useful tools for predicting the behavior of 'fresh' material. However, studying the effects of weathering in the field on the actual rock dumps, leach pads and pit walls, rather than in the laboratory with tests such as humidity cells, is the best indication of the geochemical behavior of material that has already been mined and leached.

Since the testing program was completed for the FEIS, the materials on site have continued to weather and their associated geochemistry has evolved. Therefore, a geochemical characterization program was conducted in 1999 and early 2000. The program consisted of a widespread surface sampling program and a drilling program to test material from within the leach pads and dikes. In general, the results agree with or help to refine the conclusions made in the FEIS.

Over 400 surface samples were collected from the mine facilities and over 200 drillhole samples were collected from within the leach pads. Paste pH and paste total dissolved solids (TDS) were measured on all samples collected. Selected samples were submitted for more detailed laboratory test work.

Paste pH evaluates the existing pH of the sample and can assess the acidity due to dissolution of reaction products that have accumulated on the rock surfaces. The pH is an expression of the acidity or alkalinity of the material on a scale of 1 to 14 (normally), with 1 being most acidic and 14 most alkaline (rainwater is typically a pH of 5.5 to 5.8 s.u.). A paste pH above 7.0 s.u. may be indicative of high percentages of alkaline minerals.

Paste TDS is a measure of the soluble minerals content in a sample. The TDS is measured indirectly by the electrical conductivity of the paste. The electrical conductivity of the paste reflects the concentration of readily soluble minerals that coat the surface of the rock. These minerals are formed as a result of sulfide oxidation and, sometimes, subsequent acid neutralization. They are typically referred to as “stored oxidation products.”

Acid generating samples typically have low pH values and higher TDS values. The high TDS values reflect the presence of soluble oxidation products stored on the rocks. Those samples which have been exposed for ten or more years with neutral pH results and low TDS values are typically considered non-acid generating.

There is, however, an exception to this trend for material that has been leached on the leach pads. In the gold extraction process using cyanide, the pH of the leaching solution is kept high (around 10.5 s.u.) by adding lime or caustic soda (alkalis) to the leaching solutions. Therefore, many of the samples on the leach pads have a near-neutral to slightly alkaline pH with high TDS as a result of the alkali minerals which remain as coatings on the leached ore.

The modified Acid-Base Accounting (ABA) tests involve a measurement of the acid production potential (AP) and the neutralization potential (NP). The balance or difference between the NP and the AP indicates the net tendency for a material to either produce or consume acid. Theoretically, if the potential to produce acid is equal to the potential to neutralize acid, the sample would not result in ARD. In reality, an excess of neutralization potential is typically required to ensure acidic conditions do not arise.

Interpretation of static test results typically involves using regulatory criteria to classify the samples as to their potential to generate or consume acidity. The evaluation criteria used in the FEIS (pp. 3-20 to 3-22)

was that proposed by the British Columbia Acid Mine Drainage Task Force (1989) as revised by the Montana Department of Environmental Quality based on subsequent kinetic testing (Miller 1995).

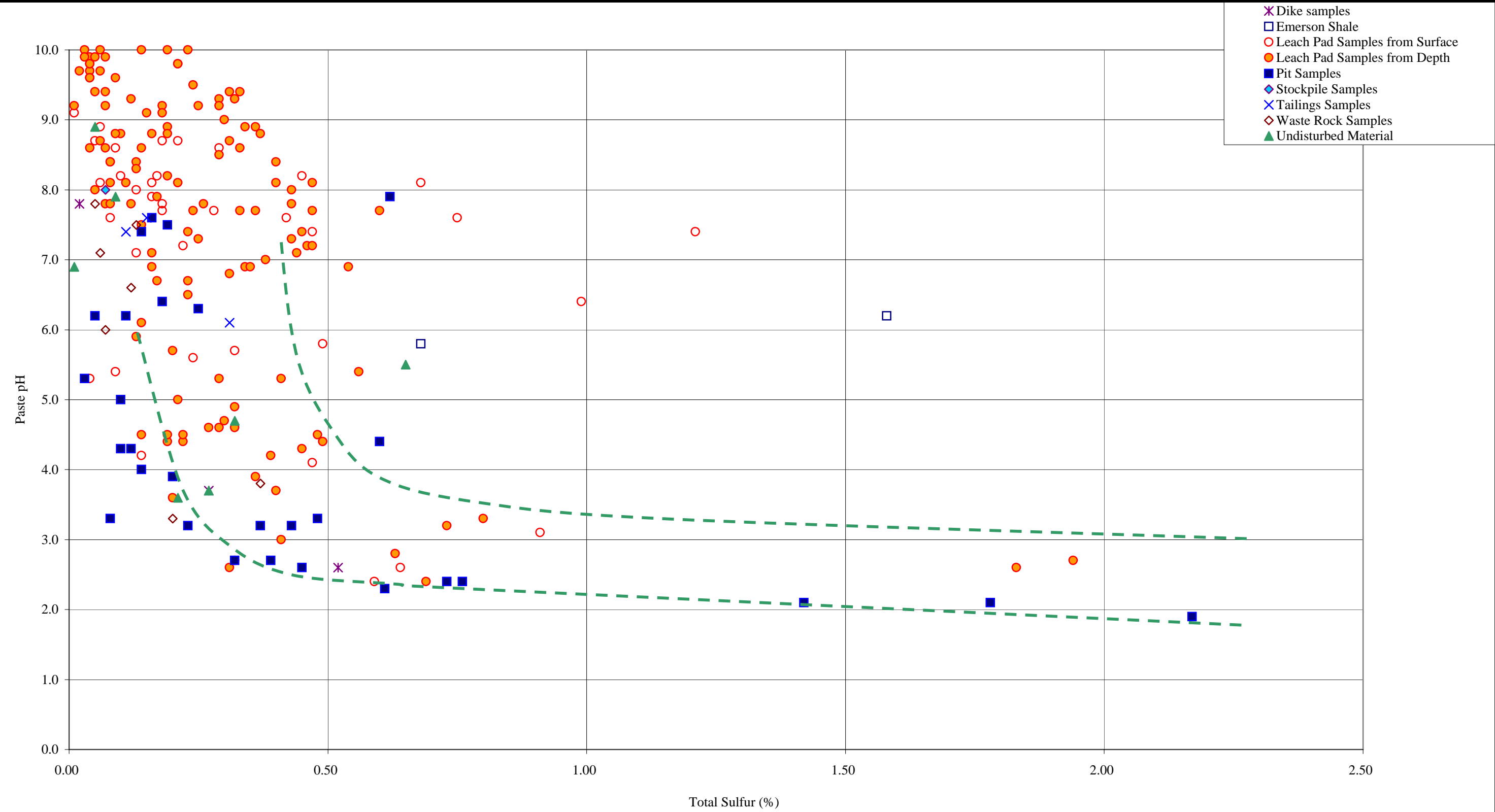
The extensive and thorough testing programs carried out on site for the FEIS and during the follow-up testing have allowed further clarification and, where necessary, revisions to the classification of material on both sites. In general, there is very little neutralization potential in the vast majority of material on-site. Figure 3.3-1 is a plot of total sulfur versus field paste pH. Nearly all samples (excluding the leach pad samples) with total sulfur contents greater than 0.2% have field paste pH values less than 5.0. This percentage of sulfur is far less than would be visible with the naked eye. There are also some samples with total sulfur values less than 0.2% that are acidic. In other words, a sulfur cutoff value of 0.2%, as proposed by ZMI in 1993, is not necessarily protective of the environment. This is the same conclusion that was reached in the 1996 FEIS (p. 3-43).

The neutralization potential in the leach pad samples has been augmented by the addition of alkalinity during the leaching process. It is anticipated that once the alkalinity in the leach pad samples is exhausted, these samples would also plot within the dotted lines on Figure 3.3-1, outlining the apparent natural trend of the other materials on site. Some of the leach pads are expected to become highly acid generating over time, including the L87/91, Z82 and Z85/86 leach pads. Others, however, appear to be only very slightly acid generating to neutral with respect to acid drainage. These include the lower Landusky Mine leach pads and the Zortman Mine Z83, Z84 and Z89 leach pads. The L85/86 leach pad may contain excess alkalinity and be a source of non-acid generating material suitable for use in construction of the reclamation covers.

Figure 3.3-2 is a typical plot showing the results of the modified ABA testing plotted as neutralization potential (NP) versus acid potential (AP). Guidelines suggest that samples plotting above the 1:1 line should be considered potentially acid generating, those plotting below the 3:1 line should be considered non-acid generating, and those falling between the two lines should be classified as 'uncertain' with respect to acid generating potential. The vast majority of samples from the mines are classified as potentially acid generating.

Another graph used for interpretation is that shown in Figure 3.3-3, which plots paste pH against the net acid potential (AP minus NP). Those samples with excess acid potential (positive values) would be classified as either currently acid generating (such as the pit wall samples) or potentially acid generating (such as most of the leach pad samples). Again, the information shows that most of the material is either currently or likely to become acid generating. The acid generating potential ranges from fairly high to very slight. Actual generation of acidic drainage depends upon the location of the material in the field with respect to water, oxygen, and potentially neutralizing rock material.

Based on these results, the amount of readily available NAG material on site is limited. Although limited, the NAG material that has been identified is easily segregated from potentially acid generating material. In general, the materials at the Zortman Mine with consistently non-acid generating test results and suitable for use as covers or construction are the topsoil samples, the Ruby Gulch tailings and the Goslin Flats soils.



Source: Robertson GeoConsultants Inc. 2001

PASTE pH VERSUS TOTAL SULFUR

FIGURE 3.3-1

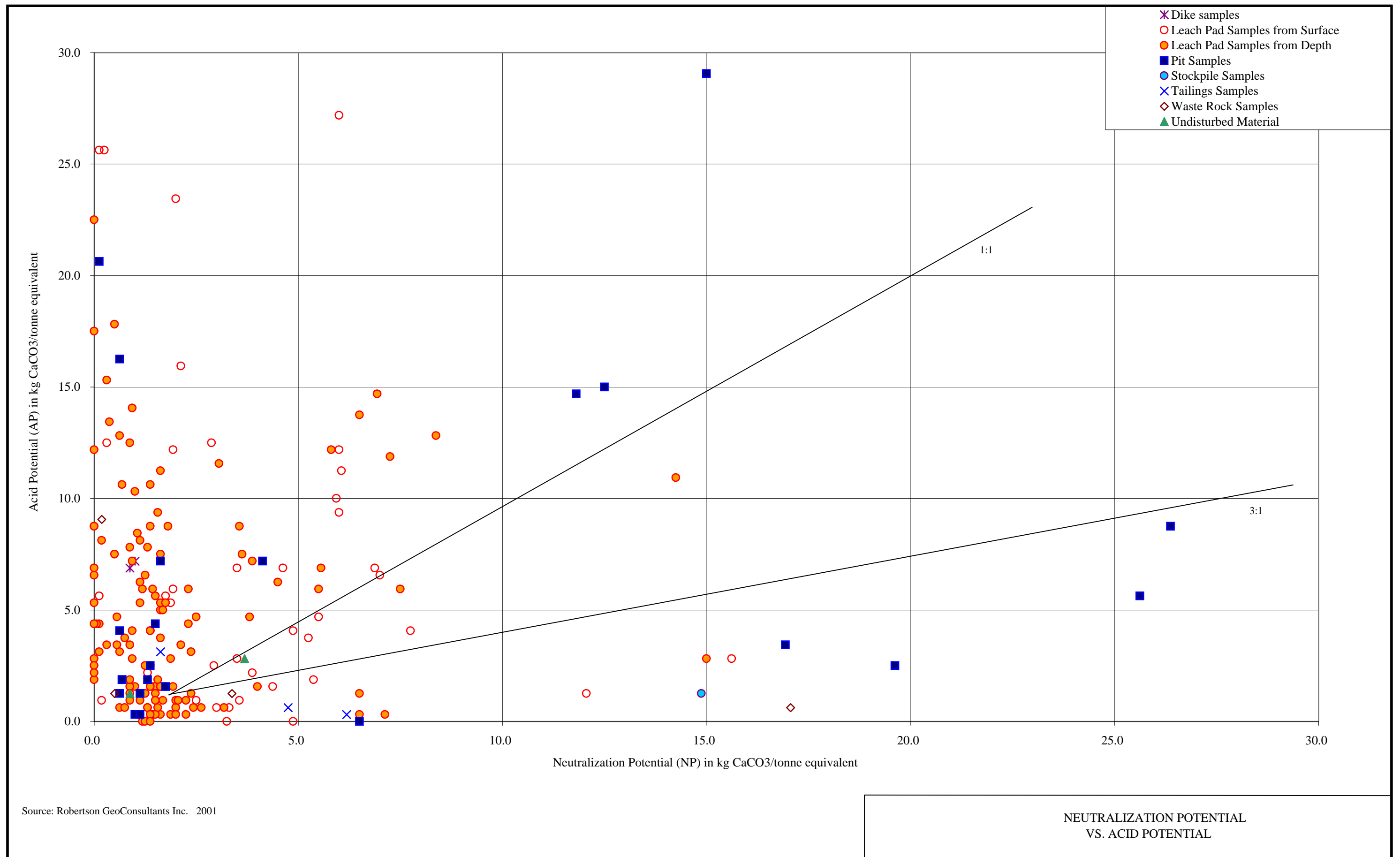
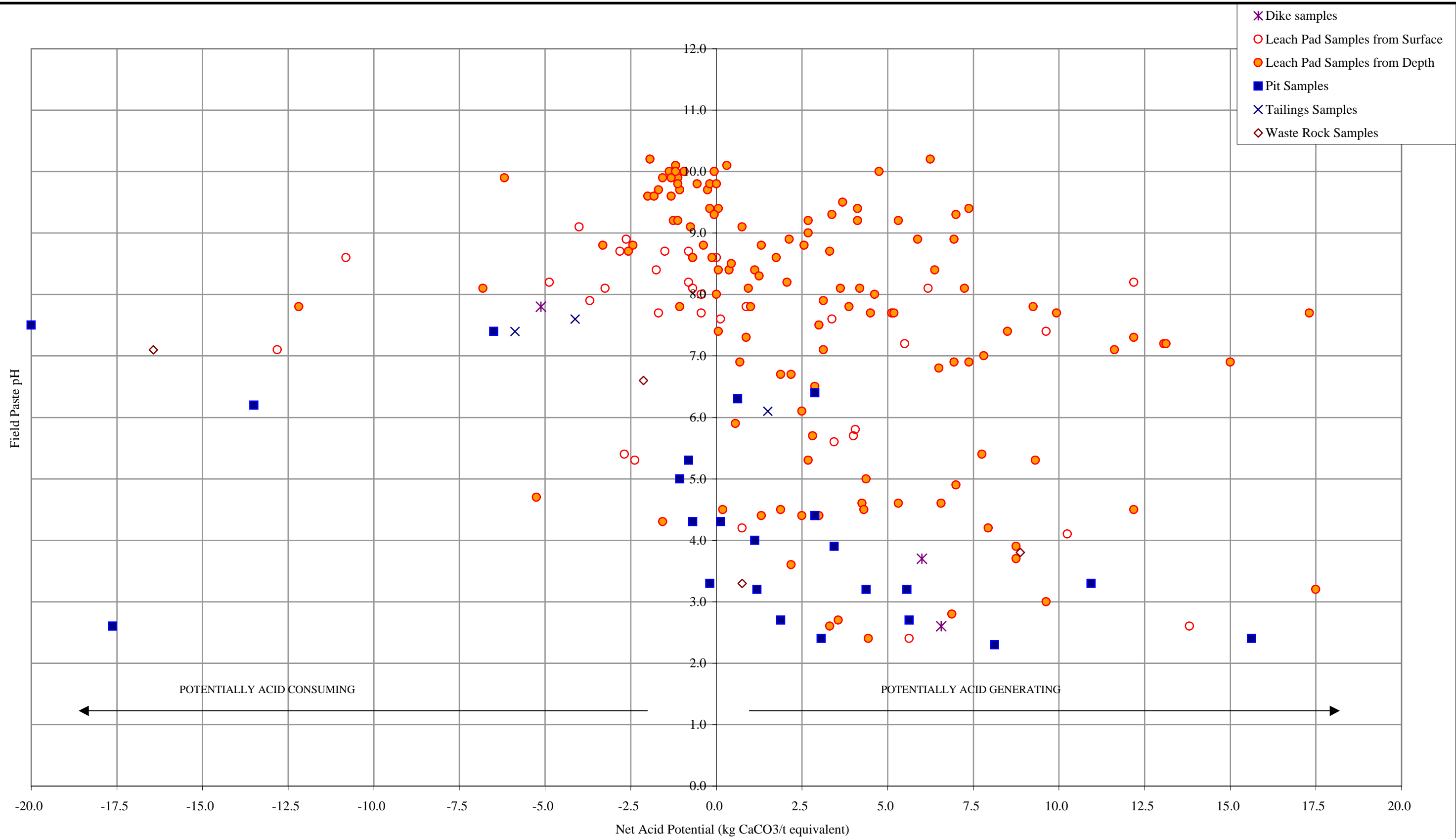


FIGURE 3.3-2



Source: Robertson GeoConsultants Inc. 2001

PASTE pH VERSUS NET ACID POTENTIAL

FIGURE 3.3-3

At the Landusky Mine, the material types showing consistent non-acid generating characteristics are the stockpile samples, which include the Gold Bug limestone stockpile, Bighorn dolomite stockpile, Gold Bug blue waste (non-acid generating) stockpile, and the topsoil stockpiles. The L85/86 leach pad material also appears to be non-acid generating, suitable for use as NAG underlying the cover on backfilled material.

Some on-site rock has not been identified as NAG material, but is not necessarily a net acid generating material. The lower Landusky Mine leach pads and the Z83, Z84 and Z89 leach pad complexes appear to fall in this category. In fact, quality control testing completed in conjunction with the interim reclamation measures has identified very few and only surface localized areas on these leach pads that require the addition of lime to maintain neutral pH conditions.

### Geochemical Findings

The 1996 FEIS contained a section on geochemical findings (pp. 3-45, 3-46). Based on additional studies, many of those findings have been confirmed or slightly revised. Some, however, are no longer appropriate due to the cancellation of the mine expansion proposal. The findings that apply to current conditions or potential reclamation alternatives under evaluation have been reproduced here. Any edits modifying the results in light of the additional studies are provided in *italics*.

1. ARD is currently being generated from pit walls and floors, leach pads and pad foundation (L91 leach pad), and waste rock piles at the Zortman and Landusky Mines.

*Not all leach pads should be considered acid-forming. The lower leach pads at the Landusky Mine and the Z83, Z84, and Z89 leach pad material are only very slightly acid generating material, suitable for use in reclamation.*

2. The groundwater in the Thermopolis shale at Goslin Flats has naturally high TDS, alkalinity and sulfate. However, the leach pad foundation (*no longer proposed*) is unlikely to be a source of acid due to its fine-grained nature, relative impermeability *and inherent neutralization potential*.
3. Ore produced as a result of the *past mining operations* has acid producing potential. Leachates from spent ores initially have alkaline pHs, relatively high TDS *and nitrate* concentrations, and high concentrations of elements mobile at alkaline pHs such as arsenic, selenium and molybdenum. However, as remnant sulfides react, subsequent leachates *would likely* become acidic and contaminated with dissolved metals. *Certain leach pads have already become acidic (e.g. Z82 leach pad) and the water is first treated in the water treatment plant, or with in-situ lime addition, to raise the pH and remove metals before being applied to the LAD for nitrate treatment.*
4. For waste rock at both mines, there is a direct relationship between percent sulfur and net neutralization potential (NNP). Almost all sulfur is reactive and excluding the limestone,

amphibolite, shale and dolomite, the waste rock has very little neutralization potential. For both mine sites, *use of waste samples having negative NNP as parameters for classifying waste is effective.*

5. Where the paste pH was 6.0 s.u. or above, acidic pHs in humidity cell leachates were not produced. Samples with a paste pH less than 6.0 s.u. identified low sulfur rock types which had already gone acid or contained stored oxidation products. Therefore, use of paste pH as a parameter for *classifying waste is appropriate.*
6. All low to medium sulfur, 0.8 weight percent or less, amphibolite appears to be non-acid forming and could be used for construction, fill or reclamation purposes.
7. Syenite waste rock containing less than or equal to 0.2% sulfur and of 0 T/kT or greater, does not generate acid in sufficient quantities to affect revegetation, but could affect water quality if this waste is placed where contact with surface water is likely to occur.
8. Breccia and monzonite rock types, designated as ‘blue waste’ by ZMI (*i.e. percent sulfur less than 0.2*) may generate acid or contain oxidation products sufficient to generate low pH conditions and therefore are not considered suitable for any construction, fill, underdrain or reclamation purposes. *The ‘blue waste’ comprised of Emerson shale, however, is an excellent NAG source.*
9. For other rock types: trachyte, quartzite and felsic gneiss, static data indicated that these rock types did have the potential to generate net acidity, however kinetic test data was inconclusive. *Additional field and lab testing confirms the results of earlier static testing, i.e. that these rock types are largely acid generating.* Therefore they have been excluded from use as construction, fill, underdrain, or reclamation purposes.
10. Should an insufficient quantity of suitable waste rock exist, unmineralized limestone, dolomite, and amphibolite with high NNPs would be available for construction, reclamation, or remediation activities in sufficient quantities. *However, to obtain these quantities it is likely that the material will need to be quarried from nearby sources.*

### 3.3.3 Hydrology

#### New Hydrological Data

The 1996 FEIS noted that ZMI monitoring wells were predominately located near or at the base of drainages, making the water table difficult to define (FEIS, p. 3-49). In addition, during the EIS review process it was determined that there were not enough groundwater monitoring wells located north of the Zortman Mine where the mine pit expansion was proposed. Therefore, construction of new monitoring

wells and surface water monitoring stations were required in 1996 (FEIS, pp. 2-102, 2-193, 2-208 and 2-235). Also in 1996, ZMI agreed to perform a Groundwater Investigation under the Consent Decree. Nineteen new wells and six new piezometers were installed for this Groundwater Investigation, along with 19 new surface water stations. Many of the surface water sites were in the Swift Gulch and Lodgepole Creek drainages (WMCI, pp. 41-54).

Besides the data obtained from the new monitoring well and piezometer completions, a considerable amount of new information has been obtained regarding surface and groundwater conditions, from:

- Four synoptic stream surveys utilizing over 90 new surface water stations;
- Regional and local spring and seep surveys - with up to 33 mine sites and regional sites;
- Hydraulic testing of new wells;
- Long-term pump test (68 days) on ZL-302 (located in the northern Zortman Mine area);
- Monthly, bi-monthly, and semi-annual water chemistry samples for all new wells;
- Long-term artesian flow test of WS-3 with water quality data;
- Quarterly or semi-annual groundwater and surface water sampling from Fall 1996 through October 2000;
- Baseline hydrologic studies of the Goslin Flats LAD expansion areas and the proposed Landusky LAD area;
- Periodic special purpose groundwater and surface water monitoring data collections, e.g. Swift Gulch springs and seeps; and
- An EPA sampling program of domestic water supplies on the Fort Belknap Reservation during the year 2000.

Further information regarding the types and quantity of new data are contained in Gallagher (1999) and HSI and Gallagher (2001).

### **Regional Hydrology**

The hydrology of the area surrounding the Little Rocky Mountains has been investigated in several reports, including Alverson (1965), Feltis (1983), Briar and Oellermann (1993), and Slagle and Christensen (1993). Sedimentary rocks are the primary sources of groundwater along the flanks of the range and on the plains adjacent to the range. A significant difference, however, is that the rock units exposed in the Little Rocky Mountains are typically buried deep beneath the plains. These regional units, specifically the Madison Group, are recharged from 100 to 150 miles to the south and southwest and have significant differences in water chemistry from the locally recharged rock units of the mountains.

The U. S. Geological Survey (USGS) has maintained flow and water chemistry stations on drainages around the mountains, including Little Peoples Creek and Lodgepole Creek. Groundwater that originates within the Little Rocky Mountains appears to provide a small portion of the recharge to the valley fill alluvium in Rock, Little Peoples, Lodgepole, Ruby, Grouse, Dry, and Beaver Creeks. However, water

levels in unglaciated portions of Little Peoples and Lodgepole Creeks vary by as much as 33 feet annually, indicating the majority of recharge to the alluvium is from surface water flow in the creeks.

Potential sources for domestic, municipal, livestock, and irrigation water on the north and northwestern flanks of the Little Rocky Mountains include: Quaternary valley fill sediments, the Lodgepole and Mission Canyon Limestones of the Mississippian Madison Group, the Virgelle member of the upper Cretaceous Eagle Sandstone, the basal First Cat Creek Sandstone of the Cretaceous Colorado Group, and the basal Third Cat Creek Sandstone of the lower Cretaceous Kootenai Formation. Other rock units identified as potential aquifers for limited water supplies include the Cretaceous Thermopolis Shale and Judith River Formation sandstones.

Flow directions in the regional units are generally northward (northeast on the eastern side of the mountains and northwest on the western side of the mountains). Many of the deeper regional units are recharged by underlying strata with an upward flow gradient. Briar and Oellermann (1993) found that water level data indicated localized flow in the Virgelle Sandstone away from the northwestern flank of range, suggesting that some recharge to the sandstones may be derived from groundwater discharge from the range.

The Interior Board of Land Appeals (IBLA) in several administrative reviews conducted in 1998 on the proposed mine expansion and reclamation plan was concerned that too little information was known about the local and regional groundwater flow, including the Madison Group aquifer (IBLA, May 1998, pp. 177, 178, 186 and 197). Because of the importance of this aquifer, the local and regional Madison Group are described in more detail in Section 3.3.8.

## **Mine Site Hydrology**

### **Surface Water Occurrence**

#### Zortman Mine

The Ruby Creek drainage, which includes the tributaries of Alder Gulch, Ruby Gulch and Goslin Gulch, is the major southern drainage in the Zortman Mine area. Tributaries of Alder Gulch include Carter Gulch, Alder Spur, and Pony Gulch. Lodgepole Creek, Ross Creek and Glory Hole Gulch drain the northeastern side of the Zortman Mine (FEIS, p. 3-46). A map of the Zortman Mine drainage areas is presented in Figure 3.3-4, showing the outline of the current surface water drainage basins and drainage features.

Since the 1996 FEIS, additional data have been collected and interpretations have been updated regarding trends in mine site drainage. There have also been changes in the surface water drainages near the Zortman Mine due to completion of the permanent capture systems in Ruby Gulch, Alder Spur and Carter Gulch.

Water balance results, which are based on surface watersheds and do not include leach pads, show that the capture systems in Ruby Gulch, Alder Spur and Carter Gulch capture all but 1.2%, 6.6%, and 1.2%,

respectively, of the total precipitation falling over these basins. The non-captured water is generally surface water flows during large storm events that are conveyed off-site by the network of diversion ditches. In extreme precipitation events, some water overflows the capture systems and moves down the drainage. Information regarding the methods used and results of individual capture system water balances at both mines are presented in HSI and Gallagher (2001). A description of the components of the capture systems is also included in HSI and Gallagher (2001).

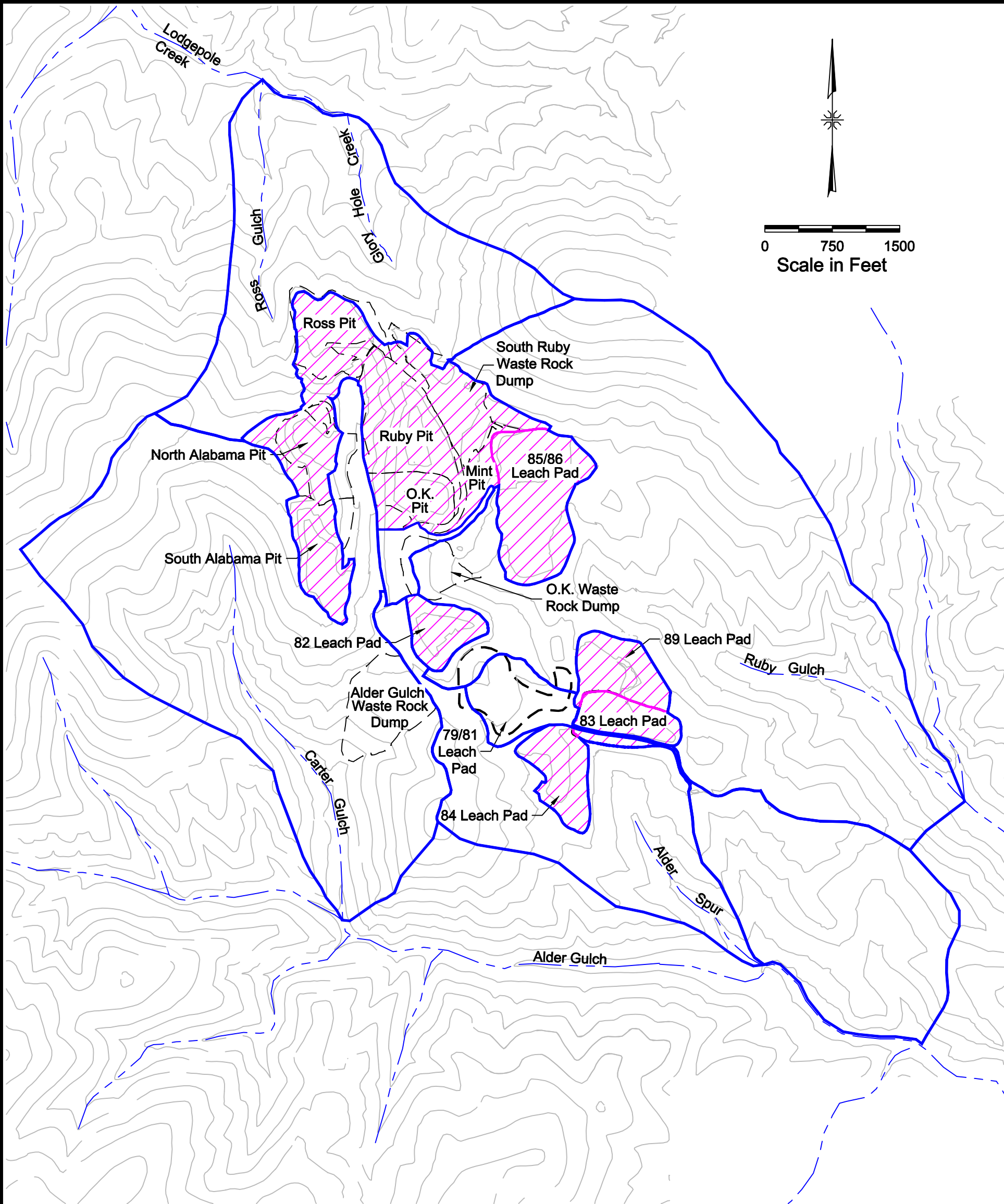
Captured surface flows from Ruby Gulch, Alder Spur, and Carter Spur are pumped to the Zortman water treatment plant. Due to the intermittent flows in these drainages and the large storage pond in Ruby Gulch, the water treatment plant operates only intermittently. Ruby Gulch receives all treated discharge from the Zortman water treatment plant. This discharge constitutes the majority of flow in the drainage.

Goslin Gulch originates between Whitcomb Butte and Saddle Butte about one mile south of Zortman and trends south to join Ruby Gulch 2.6 miles south of Zortman. The valley and flat areas around Goslin Gulch are collectively referred to as Goslin Flats. A 364-acre LAD area is located on Goslin Flats. Information on Goslin Gulch water quality is presented in Section 3.3.6.



#### Landusky Mine

The southern portion of the Landusky Mine area is drained entirely by Rock Creek and its tributaries. Major tributaries to upper Rock Creek include Sullivan Gulch, Mill Gulch and Montana Gulch. The northern portion of the Landusky Mine area is drained by Little Peoples Creek tributaries, South Big Horn Creek and King Creek. Swift Gulch is a tributary to South Big Horn Creek (FEIS, p. 3-47). A map of the Landusky drainage areas is presented in Figure 3.3-5, showing the outline of the current surface water drainage basins and drainage features. Seepage capture systems have been constructed in Sullivan Gulch, Mill Gulch, upper Montana Gulch, and lower Montana Gulch. Water balance results, which are based on groundwater basins and do include leach pads, show that the seepage collection systems captured all but 38.2%, 6.6%, 0%, and 1.2%, respectively, of the total precipitation falling over the above-listed basins. The non-captured water is generally surface water flows during large storm events that are conveyed off-site by the network of diversion ditches. During extreme precipitation events, some water overflows the capture trenches and moves down the drainage.

The Sullivan Gulch, Gold Bug and Lower Montana Gulch groundwater basins include significant areas covered by leach pads. The 38.2% that is not caught by the Sullivan Gulch seepage capture system includes the precipitation which falls on the L91 leach pad plus stormwater runoff. These waters are not suppose to enter the seepage capture system. Water the falls on the leach pads is captured by the liner in the leach pads and is treated as process water. Surface runoff that does not infiltrate through potentially acid generating rock is routed around the capture systems as stormwater.

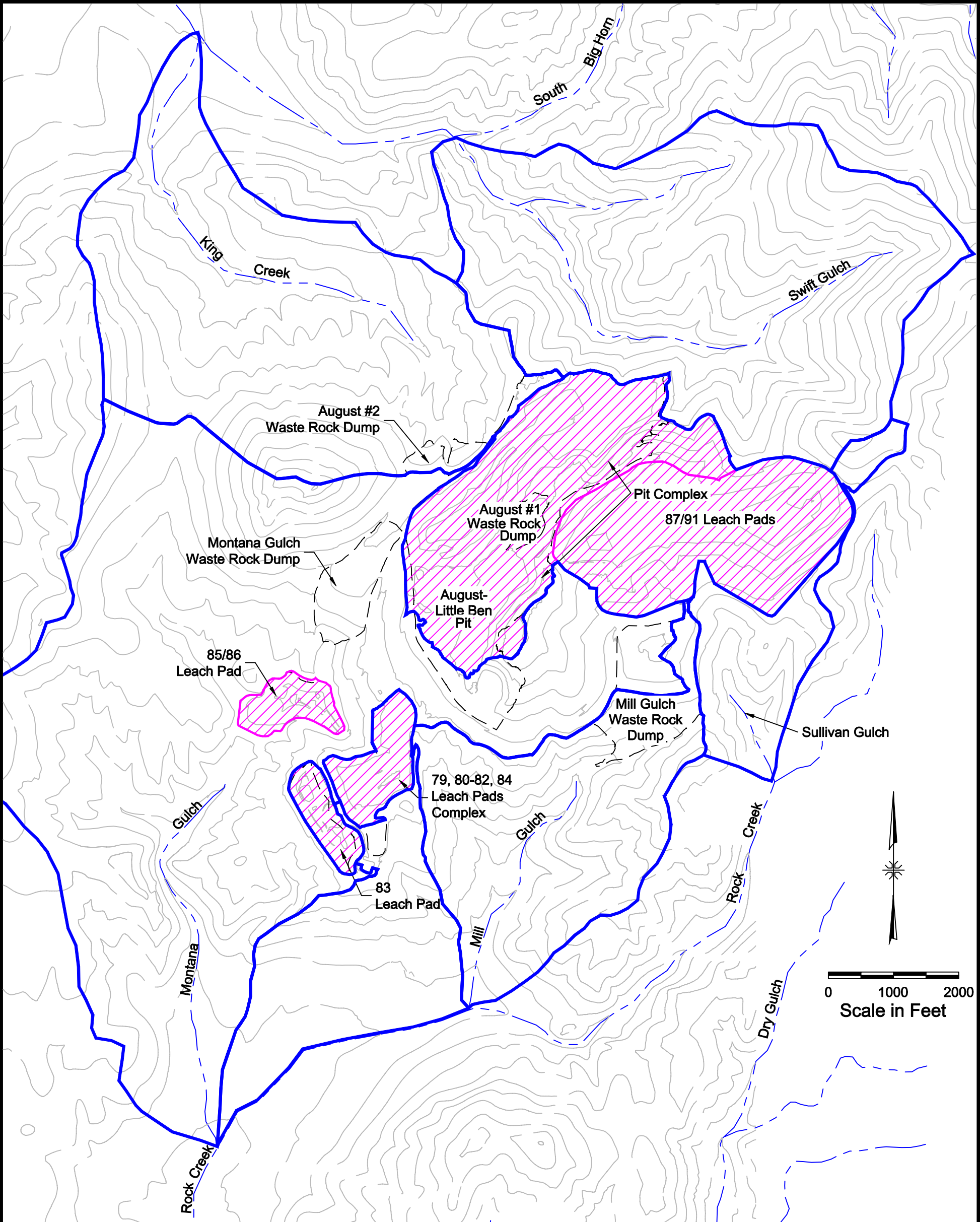




**Legend**

-  No runoff, Internal Pit Drainage or Contained Leach Pad as of 1/1/2001
-  Surface Water Basin

**ZORTMAN MINE  
DRAINAGE AREAS**

FIGURE 3.3-4



- Legend**
-  No Runoff, Internal Pit Drainage or Contained Leach Pad as of 1/1/2001
  -  Surface Water Basin

# LANDUSKY MINE DRAINAGE AREAS

FIGURE 3.3-5

The estimated uncaptured seepage derived from the chemical load method is provided in Table 4.3-4 and is 0.35 gpm for Sullivan Gulch. The average seepage capture rate in the Sullivan Gulch seepage capture system was 12.54 gpm from 9/19/97 through 12/31/99. There is a 97.2% capture efficiency with regard to the water the seepage capture system is intended to collect.

Captured surface flows from Sullivan Gulch, Mill Gulch, upper Montana Gulch, and lower Montana Gulch are pumped to the Landusky Mine water treatment plant. Water from flowing artesian well WS-3 is also captured and sent to the water treatment plant. Montana Gulch receives all treated discharge from the Landusky Mine water treatment plant.

No seepage collection systems have been constructed in either King Creek or Swift Gulch. There is a small amount of seepage from the August #2 waste rock dump at the head of King Creek and numerous small diffuse seeps in the Swift Gulch drainage. To date, impacts from the seepage in these drainages have not warranted construction of capture systems like those used in the southern drainages. Passive treatment systems may be developed in the future, dependent upon water quality monitoring results at these locations.

### **Surface Water/Groundwater Interaction**

It has long been known that surface water and groundwater are closely tied at the mines (FEIS, p. 3-106). For instance, monitoring data demonstrate that surface runoff infiltrates in the pits to become groundwater recharge. Groundwater flow then leaves the mine pit areas as shallow surface water discharge to the capture systems. At the Landusky Mine, pit infiltration discharges to the Gold Bug adit, August drain, artesian well WS-3 (when flowing), and springs and seeps in Swift Gulch.

In order to more quantitatively address groundwater and surface water interactions, synoptic stream surveys were conducted for the Groundwater Study. The results of these surveys indicate that, in general, the upper portions of the drainages contain gaining reaches, while the lower portions contain losing reaches. This means that flow in the upper reaches of the streams is increased by inflow of groundwater and the streams are losing water to groundwater in the lower portions. Hence, the potential for infiltration to impact deeper groundwater at higher elevations is low (WMCI, p. 184).

The 1995-1997 Groundwater Study analyzed surface water-groundwater interaction. The water balances prepared for the Zortman Mine (Spectrum 2000a) and Landusky Mine (Spectrum 2000b) have quantified recharge, infiltration, evapotranspiration, and discharge as a percentage of available precipitation. This analysis is summarized in Section 3.3.4. Results of the water balance calculations show there is evidence of considerable interaction between groundwater and surface water in the mine areas. The hydrology evaluations indicate that the flow pathways are predominantly shallow and intermediate in depth.

## **Groundwater Occurrence**

A number of factors influence groundwater occurrence and flow at the mine sites. While the geology lays the framework for groundwater conditions, the rock units must have “recharge” or additions of water. Precipitation and runoff infiltrating through the soil into the rock units are the primary sources of recharge. The surface topography determines where the runoff will flow on the surface and where it will ultimately infiltrate to groundwater. There is less infiltration of water into the subsurface in steep areas with dense vegetation. Conversely, there is more infiltration of water into the subsurface in flatter areas with little vegetation, such as open pits. The amount of infiltration to the subsurface ultimately determines water levels in the aquifer. Once in the subsurface, the geologic structures control water flow, including how quickly and in which direction water will travel. Man-made modifications to geology such as the underground workings beneath the mine sites or the capture systems in the drainages also affect flow directions and rates.

### **Recharge**

The surface and groundwater systems are maintained by annual recharge from precipitation, runoff, and snowmelt. Recharge to groundwater is normally a very small fraction of annual precipitation. However, it is greatly increased by mine facilities, especially open pits, unreclaimed waste rock dumps, and disturbed ground. Recharge is also enhanced in years of above normal precipitation and during episodes of successively wet or cool weather.

Recharge to the mine site aquifers was estimated in the water balance reports (Section 3.3.4). The water balance for the Zortman Mine (Spectrum 2000a) shows that 52.1% of the precipitation, or 313 gpm (on a mean annual basis over the mine site), becomes runoff (7.8%) or groundwater recharge (44.3%). The water balance for the Landusky Mine (Spectrum 2000b) shows that 45.1% of the precipitation, or 779 gpm (on a mean annual basis over the mine site), becomes runoff (2.1%) or groundwater recharge (43%).

### **Geology**

Once in the subsurface, groundwater flow is controlled by the geologic materials comprising the aquifer. The primary aquifers are bedrock aquifers. These include mineralized and unmineralized syenite and other igneous and metamorphic rock types. Paleozoic sedimentary rocks that serve as aquifers, including the Madison Group, are located downstream from the mine sites (SEIS Section 3.3.8).

The primary permeability of the bedrock aquifers (the rate of water movement through the pores of the rock) is low. Therefore, secondary porosity in the form of faults, fractures and shear zones is necessary for the bedrock units to effectively produce water (WMCI, p. 193).

The IBLA stated the FEIS provided little information on the effects of specific faults, fractures, shears, and other features on groundwater movement (November 1998, pp. 4 and 5; May 1998, pp. 197 and 200).

They indicated a lack of analysis of the geology kept the agencies from understanding groundwater flowpaths and where capture systems might intercept contaminated groundwater.

Most of the geologic information currently available was also available for the FEIS, but was not organized into a specific report. The FEIS utilized Water Management Consultants Inc.'s August Pit Study (1995), a report by Golder Associates (1996), and maps of the shear, fault, joint, and underground workings distributions provided by ZMI. Since the FEIS was prepared, the "Geologic Evaluation of the Zortman and Landusky Mine Sites and Surrounding Little Rocky Mountains" (ZMI 1996) was completed. This report includes detailed geologic maps and associated cross sections illustrating relationships between the hydrostratigraphic units, structures, and mine facilities.

The geology and structural geology are described in SEIS Section 3.2, including a discussion of shear zones at the mines. The shears are highly fractured zones which are interconnected within each of the mining areas. Since the shear zones are the primary host environment for gold and other hydrothermal mineral deposits, they were also the target for underground workings. A geologic map with shear zones, underground workings, monitoring stations, and groundwater level contours as of October and November 2000 is available in HSI and Gallagher (2001). The following sections describe the important geologic features affecting groundwater flow.

#### Geologic Structures Affecting Groundwater Flowpaths

The shear zones and associated underground workings are major controls for groundwater flow at both mines. Groundwater flows from the surrounding elevated areas laterally into the shear zones. The shears act as long lateral sinks that contain significant amounts of groundwater in storage, and discharge primarily through the underground workings out the old mine adits (WMCI, p. 197). Historic and recent blasting and mining activities may have further enhanced the permeability of the shears. Additionally, underground workings following the shear zones below the water table may connect otherwise discontinuous and unconnected fractures, enhancing groundwater movement along and through the shear zones (WMCI, p. 147). These zones have relatively high hydraulic conductivity compared to the surrounding areas. This is evident by the relatively flat potentiometric surface near the Ruby-Ross shear zone at the Zortman Mine and near the August, Niseka, Surprise and Gold Bug shear zones at the Landusky Mine.

While it has long been known that the shears and underground workings influence site groundwater flow, additional data collected during and since the Groundwater Study has emphasized the importance of these structures. The long-term (approximately three month) aquifer test of well ZL-302 at the Zortman Mine showed the hydraulic connection between wells located in the center of the shear zone. Wells located outside the shear zone did not show similar responses (WMCI 1998).

At the Landusky Mine artesian well WS-3, located 0.52 miles from the August pit in Montana Gulch, has been a major discharge point for the shear zone since it was constructed in 1984. When WS-3 was closed, a pit lake formed. When the well was re-opened, the pit lake drained within five months.

Monitoring of water levels in other wells identified interconnection through the shear zones. Additional information can be found in HSI and Gallagher (2001).

Similar high conductivity shear zones were not observed outside of the mining areas, except for the Surprise shear zone which extends from the north end of the Surprise pit across Swift Gulch to the north. Some drainages appear to be aligned with major faults which may collect groundwater flowing toward the drainage and facilitate its movement along the drainage. High conductivity discrete fracture zones were observed in some wells outside of the mined shear zones which do not appear to correlate directly to any mapped geologic faults or other structures. These zones are isolated and of limited extent, producing water mostly from storage within the rock (WMCI, p. 194).

Not all faults are effective in the conveyance of groundwater. For instance, the Narrows fault was originally suspected as a possible conduit for groundwater flow from below the Landusky pit complex toward King Creek. However, drilling and testing show that hydraulic conductivities in this shear zone are low and that groundwater elevations are higher along the Narrows fault zone than below the pit area (WMCI, p. 198).

#### Historic Mine Workings

Underground mine workings associated with the shear zones exist at both the Zortman and Landusky Mines. If located below the water level, these underground workings would be conduits for groundwater flow, creating discharge points at the adits. Some adits are located at elevations between the high and low water table elevations. In this case, oxidation products form when the water level is low and become mobilized into the groundwater system with rising levels, causing a decline in water quality. This has been documented in samples from the Zortman Mine water quality monitoring wells located in the shear zone.

*Zortman Mine:* The USGS topographic map of the area shows 11 mine adits in the vicinity of the Zortman Mine pits (some of these adits were mined out since publication of the map). Numerous other adits are shown in the surrounding area (e.g. Alder Gulch, Shell Butte, Antoine Butte). Most of these adits are above the current groundwater surface elevation and do not exhibit any groundwater drainage.

Figure 3.3-6 is a cross section through the Ruby shear zone at the Zortman Mine. The cross section shows underground workings ranging in elevation from about 4550 to 5270 feet amsl. The workings were referred to by “levels” below ground surface. According to historic reports (Bryant 1953), significant water was encountered near the 600 level (approximately 4675 feet amsl). At the 700 level (about 4550 feet amsl) water production was reported to reach a steady flow rate of 1,600 to 1,800 gpm. The workings at the 600- and 700-foot levels in the Zortman Mine area are limited in extent and are present only below the South Alabama pit and the north end of the Ruby pit. Therefore, they have limited influence on groundwater movement. Historical information does not indicate the elevation of the groundwater when mining began. However, based on the information above the groundwater level in the shear zone was probably around 4700 feet amsl.

*Landusky Mine:* Mapped historic underground workings at the Landusky Mine are shown in Figure 3.3-7. These workings range in elevation from about 4576 to 4910 feet amsl and include the former August and Gold Bug Mines. The former August Mine includes underground workings in both the August and Niseka shear zones. Of the five adits, only the Niseka adit is not covered by the Montana Gulch waste rock dump. The August tunnel, which was constructed to drain the former August Mine, discharges beneath the Montana Gulch waste rock dump and its flow cannot be segregated from the total flow at the toe of the dump. Based on daily flow data at the upper Montana Gulch capture system from October 1997 through December 1999, the normal combined discharge from the August tunnel and the Montana Gulch waste rock dump ranged from 50 to 70 gpm.

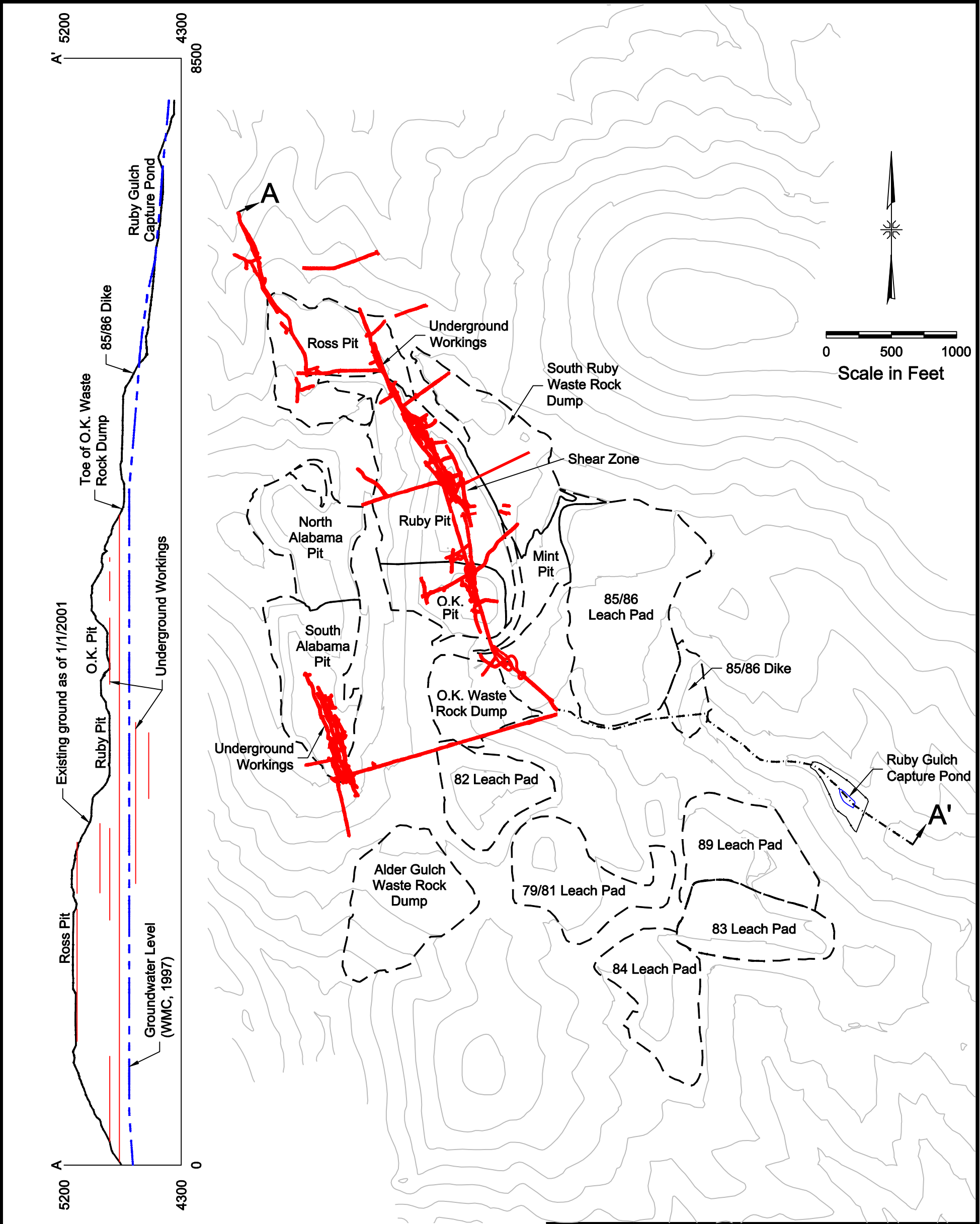
The former Gold Bug Mine includes underground workings in the Gold Bug shear zone. The full vertical and lateral extent of the Gold Bug workings is unknown, but four levels of workings have been mapped. The Gold Bug adit discharges from the deepest workings (550 level) at an elevation of 4578 feet amsl. Measured discharge from the Gold Bug adit, located approximately 1,700 feet to the south of the August tunnel portal, has varied over a wide range depending on the year, season, and method of measurement. During the period from October 1999 through May 2000, discharge averaged 145 gpm. Flow from the August drain tunnel decreased significantly after construction of the Gold Bug adit, suggesting hydraulic connection between the August and Gold Bug underground workings (WMCI, p. 195).

The August Mine is below the current groundwater surface elevation of about 4620 feet amsl. The current groundwater elevation in the Landusky Mine area indicates that the 550 and 500 level workings are probably flooded on a continuous basis. The 350 level workings (at an elevation of approximately 4674 feet amsl) may be within the zone of seasonal or periodic groundwater level fluctuation. The 300 level (at an elevation of approximately 4812 feet amsl) is always above the current range of groundwater fluctuation.

### **Groundwater Flowpaths**

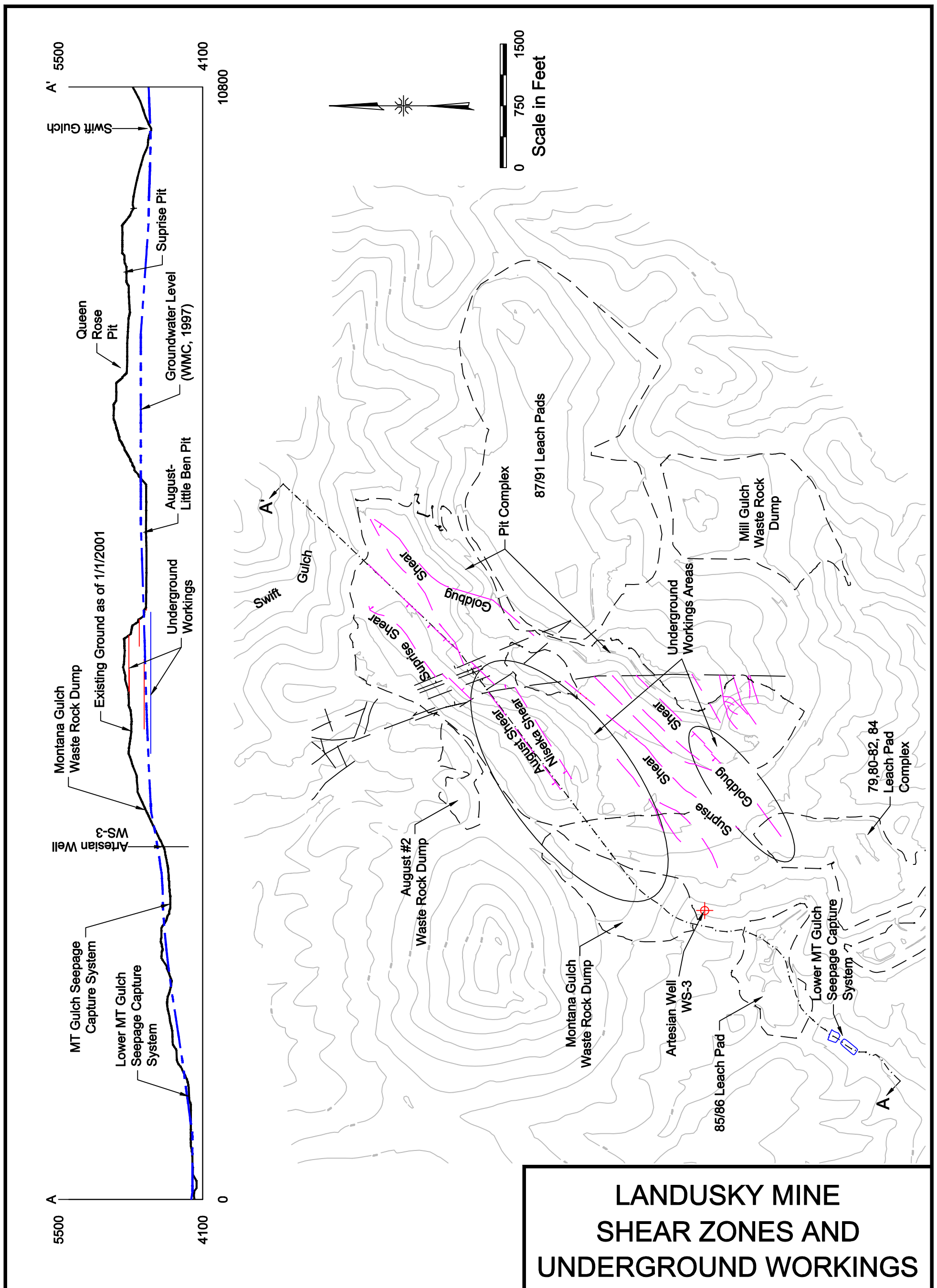
Defining groundwater flowpaths is important to understanding the migration path and rate of travel of any contaminant entering the flow system. Determining which mine facilities release contaminated water and its flowpath assist in determining appropriate reclamation.

Both the May and November 1998 IBLA decisions contained numerous references to deficiencies in the FEIS regarding groundwater flowpath information. The IBLA stated that without an understanding of groundwater flows at the mine sites, the effectiveness of reclamation measures designed to prevent and control ARD could not be evaluated. Therefore, preparation of the SEIS used data in the FEIS which has been supplemented by the data and analysis contained in the Groundwater Study's "Detailed Conceptual Hydrologic Models." The following sections contain updated information on the components of groundwater flow, including the potentiometric surface, groundwater fluctuations, and groundwater divides. The August pit lake and deep and shallow groundwater flowpaths are also discussed. Additional flowpath information can be found in Gallagher (1999) and HSI and Gallagher (2001).



**ZORTMAN MINE  
RUBY SHEAR ZONE AND  
UNDERGROUND WORKINGS**

FIGURE 3.3-6



### Potentiometric Surface

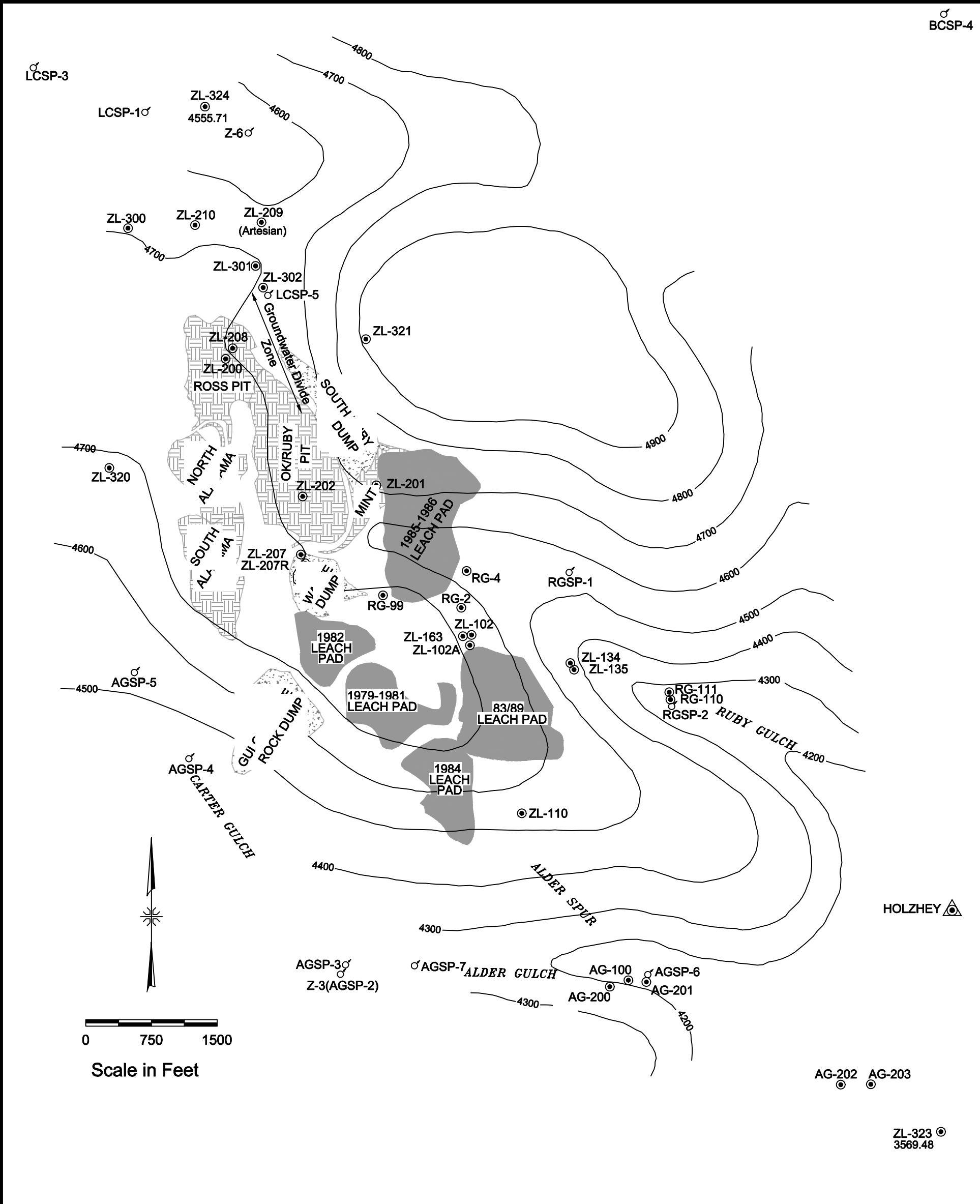
The potentiometric surface is the horizontal surface showing the potential water level of an aquifer. The water table is the top of the saturated zone of an aquifer. The hydraulic head is the level at which groundwater stabilizes in a tightly cased well open to a specific aquifer. A potentiometric surface map is made by plotting the contours of equal elevation, based on the water level in wells and piezometers, baseflow-fed streams, and springs. Determination of the potentiometric surface allows determination of groundwater divides and flowpaths.

The IBLA indicated there was inadequate data to accurately determine groundwater flow directions at the mines (November 1998, pp. 3 and 4; May 1998 pp. 177-179, 185, 187, 193-195, 197, 199 and 200). Since the FEIS was prepared, a significant quantity of data has been collected to assist in determining flowpaths. These data indicate that with the exception of the shear zone areas, the groundwater potentiometric surface generally reflects the topographic surface (WMCI, p. 196). This was also the conclusion reached in the FEIS (p. 3-49). The shear zones and underground workings have a relatively flat groundwater surface due to the high degree of hydraulic connection and permeability.

Potentiometric surface maps for the Zortman and Landusky Mine areas were prepared for both the 1996 FEIS (pp. 3-50 and 3-52) and the Groundwater Study (WMCI, Plan 5.2). As discussed above, the potentiometric surface maps show a relatively flat groundwater surface over the shear zones at each mine. To identify variations in the potentiometric surface for the SEIS, two additional maps are provided for the mine areas. Figures 3.3-8 and 3.3-9, and Figures 3.3-10 and 3.3-11 show the potentiometric surface in November 1999 and November 2000 for the Zortman Mine area and in October 1999 and October 2000 for the Landusky Mine area, respectively. The first map shows water levels prior to the start of the WS-3 aquifer test. The second map shows water levels near the end of the one year test. An additional set of maps for a May 2000 monitoring event are provided in HSI and Gallagher (2001).

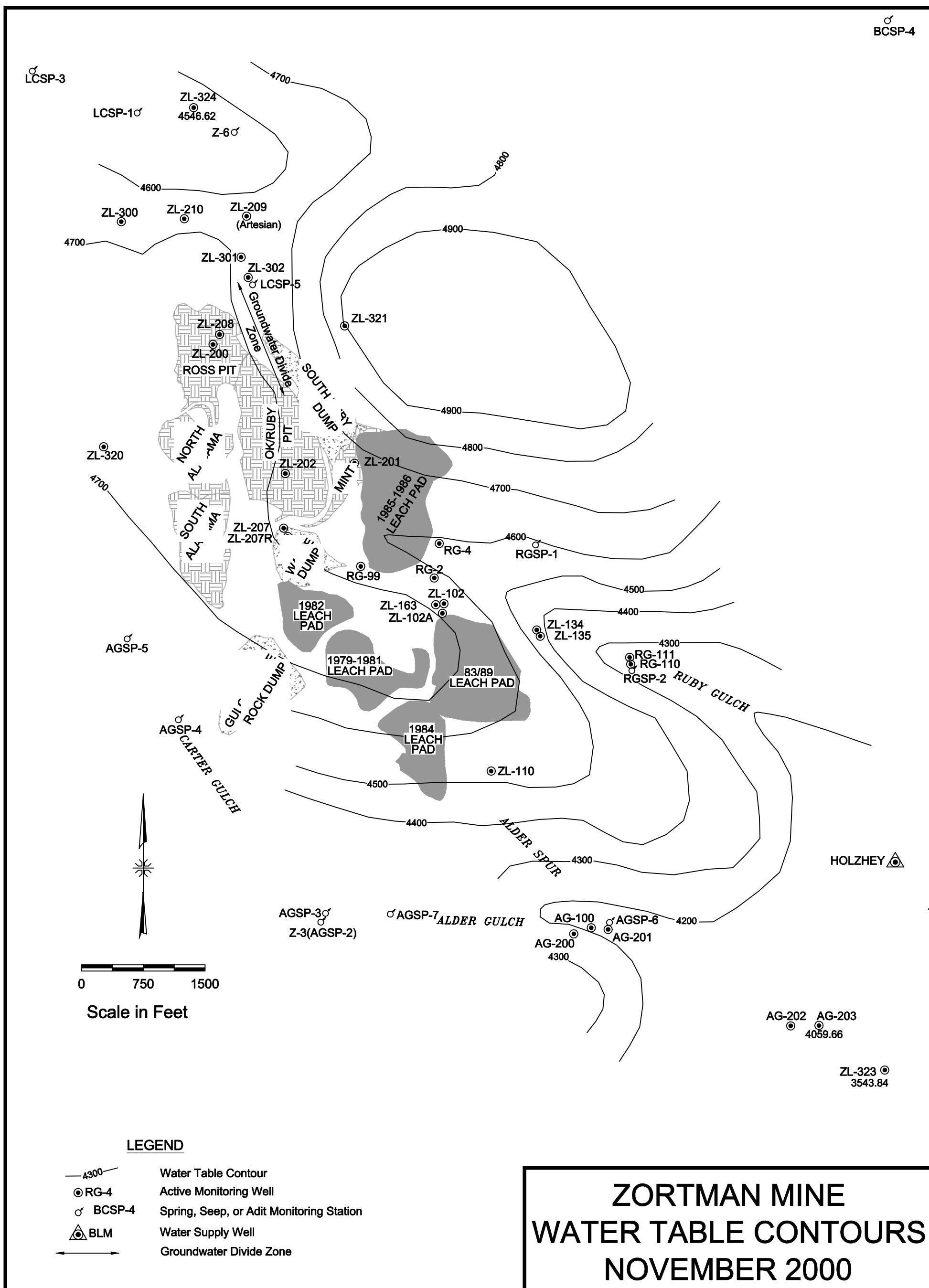
Flowpaths can be interpreted using the potentiometric map by drawing a line perpendicular to the potentiometric contour. Both the FEIS and the Groundwater Study also utilized water quality data and hydrographs to refine flowpath interpretations. New interpretations about groundwater flowpaths have also been made using the water quality classification results. A discussion of the classification system is presented in SEIS Section 3.3.5 and in HSI and Gallagher (2001). The water balance prepared for each mine also assists in defining the quantity of flows within the mine sites.

Using water level, hydrograph, water chemistry, and water balance data, it is concluded that the vast majority of groundwater from the Zortman Mine flows south into Ruby Gulch and Alder Gulch where it is captured (FEIS, p. 3-109, WMCI, p. 527, Spectrum 2000a, HSI and Gallagher 2001). The results of a long-term pumping test and the similarity of response in long-term hydrographs indicate wells in the shear zone are hydraulically connected.



**ZORTMAN MINE  
WATER TABLE CONTOURS  
NOVEMBER 1999**

FIGURE 3.3-8



**FIGURE 3.3-9**



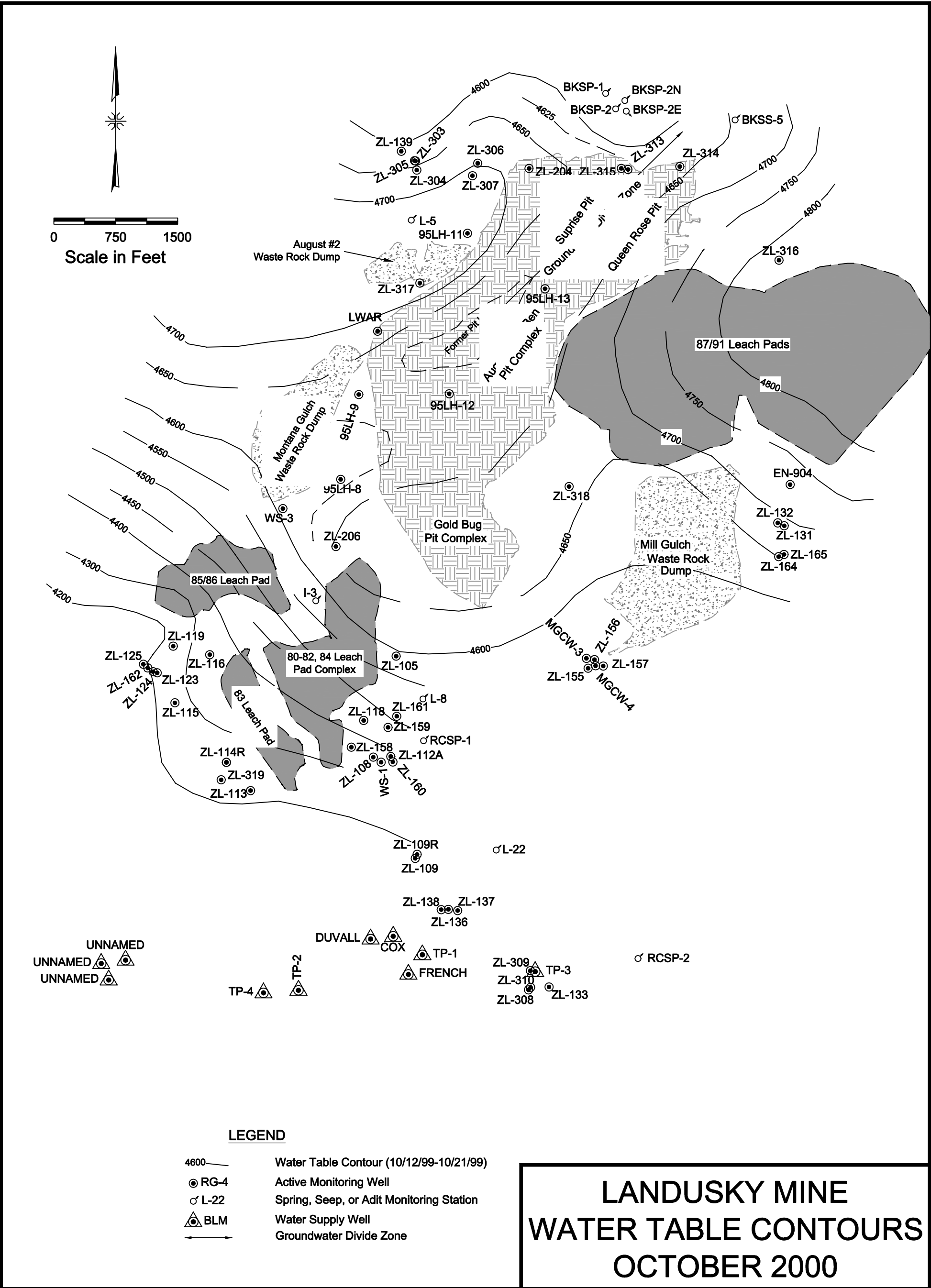


FIGURE 3.3-11

Using the potentiometric map and the hydraulic properties of the aquifer, it has been calculated that only about 3 gpm is discharged to the north from the Zortman Mine (Spectrum 2000a). This is compared to an estimated minewide 175 gpm of groundwater that is captured and sent to the water treatment plant and 12.7 gpm of noncaptured groundwater discharging to the south.

Water quality data for wells, springs and surface water in upper Lodgepole Creek contain limited evidence of mining-related impacts, indicating a minor amount of flow to the north. Acidic pH values and the metals cadmium, copper, nickel and zinc occur occasionally in upper Glory Hole Creek (spring LCSP-5). Elevated nitrate concentrations are found at surface water sites in Glory Hole Creek. However, at the lowest monitoring station (Z-5, located about 1000 feet downstream from the spring) levels are always below the nitrate drinking water standard of 10 mg/l. These nitrate levels are likely related to blasting from mining on the Ruby Gulch-Lodgepole Creek divide, west of Shell Butte. Slightly increasing sulfate levels have also been noted in upper Glory Hole Creek as shown by data from monitoring station Z-5.

At the Landusky Mine, water level data show that most of the groundwater within the shear zone is migrating along the shear zone to the southwest toward Montana Gulch and Mill Gulch (WMCI, p. 197). Southwest flow is further supported by the natural orientation of the shear zone, discharge from structures such as the August drain and Gold Bug adit, and data from dewatering the August pit (WS-3 aquifer test). Flow to the north from the Landusky pit complex shear zones was also identified in the FEIS (p. 3-109, others), WMCI (p. 197), and Spectrum (2000b).

The potential hydraulic connection across the syenite porphyry-Paleozoic boundary in the lower Landusky Mine area was evaluated with aquifer tests conducted in 2000 and 2001. The two Paleozoic wells closest to WS-3, ZL-105 and ZL-116, were monitored prior to and following the 36-day shut-in test and subsequent re-start of artesian flow from WS-3. These two wells are completed in the Ordovician Bighorn dolomite. The water levels in the two Paleozoic wells did not change due to either the shut-in or flow tests, unlike the wells in the syenite porphyry aquifer which clearly responded as expected. Based upon these test results there is a poor degree of hydraulic connection across the syenite-Paleozoic boundary.

#### Groundwater Level Fluctuations

WMCI concluded that the groundwater elevation in the shear zone at the Zortman Mine has recovered to pre-mining levels, although data indicate that water levels in some wells have been consistently rising since 1991 (WMCI, p. 194). Data from 1996 through 2000 indicate that groundwater levels continued to experience net annual increases up to the year 2000, averaging eight feet per year within the shear zone-pit area. No net increase was seen in 2000, likely due to below average precipitation. Selected well hydrographs for the Zortman Mine are provided in HSI and Gallagher (2001). Accounts of underground miners suggest that the original groundwater level was probably near the 4700-foot level (Botz and Gartner 1978). If so, groundwater has likely recovered to pre-mining levels. However, with the large areas of pits and disturbed ground, and inverted topography, groundwater recharge has also increased dramatically, allowing for higher than original water levels.

Groundwater levels at the Zortman Mine could continue to increase to an average of 4750 to 4775 feet amsl under current site conditions. It is unlikely that groundwater levels will increase significantly above year 2000 levels, due to the relatively high permeability of the shear zone and the presence of extensive underground workings at the 500 level which serve to transmit water relatively quickly to discharge points. Reclamation activities begun in 2000 would significantly reduce recharge, resulting in groundwater levels which would likely be similar to current levels.

As with the Zortman Mine, there are no pre-mining groundwater level data for the Landusky Mine. There are no available accounts by underground miners clearly indicating groundwater levels. Notes on maps of the August Mine and oral accounts of miners indicate that groundwater was not a problem on the King Creek side, but was a major problem as mining approached the Montana Gulch side. A miner's notes on the "new 400 level" of the August Mine near Montana Gulch state, "high water in drift - 4 feet deep." The 400 level portal is at an elevation of 4812 feet amsl. This notation is at a point within 300 feet of monitoring well 95LH-09. The water level in 95LH-09 has ranged from 4658 to 4637 feet from October 1999 to October 2000. Although it cannot be verified, this information suggests that groundwater levels at the Landusky Mine are now lower than prior to underground mining. Selected well hydrographs are provided in HSI and Gallagher (2001).

Since extensive workings lie beneath the current water level, groundwater levels at the Landusky Mine will be controlled indefinitely by the mine workings. The use of WS-3 as a passive discharge point for the syenite aquifer is an effective control on groundwater levels. In November 2000, WS-3 was closed and within 2 weeks groundwater started to appear in the pit. The well was opened again in early December 2000 and the levels began to drop. The potentiometric map of October 2000 is an estimate of the equilibrium levels in the absence of reclamation with artesian well open. As with the Zortman Mine, the extensive area of open pits and disturbed ground provides for greatly enhanced groundwater recharge rates. Reclamation would probably result in slightly lower water levels and reduced discharge from WS-3 and the Gold Bug adit. The groundwater divide zone would probably remain on the north side of the pit complex.

### August Pit Lake

In mid-1997, groundwater began ponding in the August pit at the Landusky Mine and reached a total depth of about 15 feet by August 1999. The pit lake began to form after the flowing artesian well, WS-3, was closed in late 1995. This 243-foot deep well is completed in syenite porphyry and is located along the alignment of the shear zone. Water levels for the northern shear zone wells had also increased approximately 10 feet coincident with filling of the pit.

Since the pit lake had major implications to reclamation of the pits, a test was conducted to determine whether flow from WS-3 was acting as a shear zone drain. The well was opened and allowed to flow on October 27, 1999. The pit level began to measurably decline after about one week, and was completely dewatered in April 2000, confirming the connection between WS-3 and the pit lake through the shear zone.

Water quality in the pit lake was typical of neutralized ARD, while discharge from WS-3 was representative of naturally mineralized groundwater. This indicates that pit lake water was either altered geochemically or diluted along the flowpath. Additional information regarding the WS-3 aquifer test is contained in HSI and Gallagher (2001).

The August drain tunnel was located below the pit lake level, but has been partially collapsed since April 1959. ZMI also drilled and shot the August pit floor after removing the last bench of ore in January 1996. The drain tunnel was about 15 feet below the final pit floor (approximately 4645 feet amsl) and was likely further collapsed when the pit floor was blasted. Aquifer testing shows that the discharge from the Montana Gulch waste rock dump (L-38) was reduced when WS-3 was flowing, and increased again when WS-3 was closed.

### Groundwater Divides

A groundwater divide is an imaginary line “dividing” groundwater basins, comparable to “watersheds” for surface water basins. The location of groundwater divides is important in order to determine if mine impacted groundwater is discharging north towards the Reservation. The location of the divide and size of the groundwater basin are key factors related to the potential quantity of water flowing to the north.

The IBLA questioned the interpretation of the groundwater divides presented in the FEIS (see IBLA May 1998 Decision, pp. 178, 194, 195, 198 and 199; and November 1998 Order, p. 3.) They were concerned the limited number of wells in the northern portions of the mine sites precluded accurate location of the groundwater divide.

Since completion of the 1996 FEIS, an additional 15 wells and piezometers have been constructed in the north end of the mining areas, including five at the Zortman Mine and 10 at Landusky Mine (WMCI, pp. 42-43). The additional data collected from the wells refined the interpretation of divides. It should be noted, however, that it is not appropriate to draw a single line on a map signifying the year-round groundwater divide. Data show the water table is relatively flat at the northern end of both mines within the shear zones, and the groundwater divide occurs as a gentle “saddle point.” Changes in precipitation, surface drainage, mining and grading patterns, land cover and seasonal trends are all forces that may cause the saddle point to shift north or south. Recent monitoring at the Crown Butte mine in southcentral Montana has also demonstrated that groundwater divides in mountainous fractured rock settings shift seasonally (M. Wireman, EPA, pers. comm. 1999).

Based on observations of water quality in springs and seeps near divides, the presence or absence of very discrete fractures trending along the shear zones may cause the “divide” to take sharp, but very narrow deviations north and south. Because the location of these fractures cannot be pinpointed, and because of the seasonal variability in factors discussed above, a single specific line on the map identifying the divide is not an accurate portrayal. The general area of the groundwater divide is known from the existing potentiometric surface map and it is more accurate to consider it a groundwater divide zone.

*Zortman Mine Groundwater Divide:* A groundwater divide was mapped for the Zortman Mine using May 1995 data (FEIS, Figure 3.2-9). It was noted that little data were available and the divide was debatable (FEIS, p. 3-49). Since completion of the FEIS, five new wells/piezometers were completed in the northern end of the Zortman Mine area in the shear zones (ZL-300, ZL-301, ZL-302, ZL-321, and ZL-324). Water level data were then collected to refine groundwater divide and flowpath interpretations. Using this new data, a potentiometric surface map was produced for the Groundwater Study (WMCI, Plan 5.2). The WMCI map shows a slightly different contour configuration than the FEIS map, but lacks definition of a groundwater divide. Both Hydrometrics (1995) and the Groundwater Study concluded the Zortman Mine groundwater divide roughly approximates the topographic divide and the shear zones complicate the exact location of the divide (WMCI, pp. 196-197).

Using 1997-2000 water level and hydrochemistry data, groundwater divide zones were delineated as previously shown in Figures 3.3-8, and 3.3-9. The Ruby Gulch-Lodgepole divide zone brackets the original surface water divide situated between the Ruby pit and the Ross pit. Where underground mine workings occur, subsurface water flow in the workings may be different than within the bulk aquifer, particularly when workings are situated near or above the normal groundwater level. This appears to occur at well ZL-200 in the Ross pit. The well penetrates an underground adit and has strong ARD impacted water quality characteristics; however, there is no evidence that this water has migrated northward.

Based on all available information, the Ruby Gulch-Lodgepole divide zone of the syenite porphyry aquifer extends from the north end of the Ruby pit and North Ruby Saddle topsoil stockpile on the south, approximately 1550 feet to the north near well ZL-301. Shallow perched groundwater such as that discharging from the ephemeral spring LCSP 5 discharges and travels in a different direction than the main aquifer flow. LCSP-5 discharges to upper Glory Hole Gulch, while at times, the flow in the main aquifer at that point may be moving south to Ruby Gulch.

*Landusky Mine Groundwater Divide:* A groundwater divide was also mapped for the Landusky Mine using May 1995 data (FEIS, Figure 3.2-10, p. 3-52). Based on the data at that time, the FEIS concluded flowpaths in the Landusky Mine area are strongly controlled by the shear zones and the Gold Bug and August adits (FEIS, p. 3-53). Some discharge to both Swift Gulch and King Creek was suggested (FEIS, p. 3-53).

Since completion of the FEIS, 10 new wells and piezometers were constructed at the northern end of the Landusky Mine area in the shear zones and King Creek (ZL-303, ZL-304, ZL-305, ZL-306, ZL-307, ZL-313, ZL-314, ZL-315, ZL-316, and ZL-317). Water level data were collected to refine groundwater divide and flowpath interpretations with the resulting map shown in Plan 5.2 (WMCI 1998). The WMCI map revealed an even larger flat area associated with the shear zones.

As with the Zortman Mine, no groundwater divide was delineated for the Landusky Mine by WMCI. Water level data did reveal most of the groundwater within the shear zone is migrating along the shear zone to the southwest towards Montana Gulch and Mill Gulch (WMCI, p. 197). The Groundwater Study

also found that groundwater flows toward Swift Gulch, but not toward King Creek as originally suspected (WMCI, p. 197). Flow toward Swift Gulch was further substantiated when the August pit filled after artesian well WS-3 was closed. Observations indicate that the discharge from springs in Swift Gulch increased as pit water levels rose.

Groundwater monitoring in 1999 and 2000 confirm the groundwater divide through the Narrows fault zone acts as a barrier to water flow from the Landusky pit area toward King Creek (HSI and Gallagher 2001). A small amount of mine-impacted water (primarily neutralized ARD) is present in King Creek, but it comes from within the watershed area itself. The primary source is the August #2 waste rock dump. The water balance/mass loading report (Spectrum 2000b) calculated 29 gpm of infiltration to King Creek from the mine area.

Groundwater divide zones for October 1999 and October 2000 are shown in Figures 3.3-10 and 3.3-11. The October 1999 map depicts groundwater levels at their highest, with 15 feet of water in the August/Little Ben pit. On October 27, 1999, artesian well WS-3 was opened and allowed to free flow at approximately 290 gpm. This well is completed in the syenite porphyry aquifer within the same shear zone occupied by the pit complex. The map for October 2000 shows the potentiometric surface was significantly lowered by the flowing well. Water levels declined from 20 to 46 feet within the pit-shear zone area. With WS-3 closed and water in the pit, the divide across the shear zone likely cut across or touched on the pit lake. With WS-3 flowing, the divide zone shifted to the north, beyond the Surprise and Queen Rose pits.

#### Perched Groundwater Flow Path

Groundwater in the form of seeps, springs and base flow discharge to stream channels in places and at elevations above the regional water table as “perched” groundwater. Perched groundwater zones occur as a relatively thin zone of water saturation, separated from the underlying regional water table by a limiting layer and a zone of unsaturated soil or rock. Perched water tables may be permanent or seasonal. Water that infiltrates beyond the soil primarily moves downward, but may be diverted laterally by geologic features such as bedding planes, fractures, or changes in rock type. Periods of high recharge enhance development of perched groundwater if the water enters the perched zone faster than it can infiltrate to lower levels.

Seasonal perched groundwater conditions occur at both mines, particularly in areas of relatively steep terrain. Springs such as LCSP-5 near the Ross pit and stream site Z-30 north of Shell Butte are examples of perched groundwater discharge sites at the Zortman Mine. Stations BKSS-1, BKSS-6, and BKSS-10 are examples of perched groundwater sites at the Landusky Mine. At these sites and certain others, the elevation of the groundwater is perched well above the regional water table or potentiometric surface.

Perched groundwater flow paths at the mines may be different than those in the underlying syenite aquifer. This has been most notably the case in the vicinity of the northern end of the shear zones, where the perched groundwater discharges to the surface drainage to the north, while flow within the main syenite

aquifer is directed to the south. To estimate the potential amount of recharge moving to perched and shallow/intermediate groundwater, three spring/stream monitoring stations with flow records were used: Z-30 at the Zortman Mine; and BKSS-1 and BKSS-10 (both in upper Swift Gulch) at the Landusky Mine.

Criteria from the mine water balances were applied to the drainage area upstream from the three monitoring stations. Estimated surface water runoff was subtracted from the observed average of all flow measurements to provide an estimate of perched groundwater discharge at each station. This was subtracted from the “Infiltration to Groundwater” component of the water balance for each drainage area to give the shallow/intermediate groundwater recharge. The perched and shallow/intermediate groundwater recharge components for the two Swift Gulch stations averaged 42% and 58%, respectively. The averages for the three stations were 56% perched recharge and 44% shallow/intermediate recharge. These percentages illustrate that the proportion of perched and shallow/intermediate groundwater circulation can vary substantially; however, they provide an indication of the observed range. A full explanation of the method and data used in the analysis is included in hydrology support document (HSI and Gallagher 2001).

#### Shallow/Intermediate and Deep Groundwater Flow Path

The 1996 FEIS noted that another component of groundwater flow is a deep, near-vertical recharge route into the porphyry bedrock and eventually into the sedimentary formations surrounding the Little Rocky Mountains (FEIS, p. 3-51). This statement was illustrated in a schematic drawing (FEIS, Figure 5.1) depicting conceptual site flowpaths.

Information collected during the Groundwater Study (WMCI, pp. 196-203), the mine water balances (Spectrum 2000a and 2000b), and monitoring data support the conclusion that virtually all quantifiable groundwater flow leaves the mine sites as discharge from the syenite aquifer to stream channels within or proximate to the mine boundaries. At the Landusky Mine, the syenite aquifer discharge is to the capture systems, Gold Bug adit, August drain, artesian well WS-3 (when flowing), and springs and seepage in Swift Gulch. At the Zortman Mine, the syenite aquifer discharges to the three capture systems and small springs, seeps and baseflow to Lodgepole Creek tributaries. Unaccounted for recharge volumes could conceivably contribute to a conceptual deep flowpath, but these amounts are small enough to be unmeasurable and within the margin of error for the hydrologic calculations employed. While hydrogeologic conceptualizations always include the deep flowpath, in the case of the Zortman and Landusky Mines it is unlikely that the deep flowpath has any significant bearing on the water quality in the sedimentary aquifers off the mine site. Additional information on the deep flowpath can be found in Gallagher (1999).

### **3.3.4 Water Balance and Chemical Mass Loading**

#### **Zortman and Landusky Mines Water Balance and Mass Loading Evaluations**

A water balance is a quantitative accounting of all principal components of the water cycle for a defined volume of earth materials or water body. It is similar to producing a balance sheet for a business. A water

balance accounts for evapotranspiration, precipitation, surface runoff, groundwater recharge and runoff, and changes in storage. A chemical mass loading model uses the results of the water balance, along with water quality data to produce estimates of the quantity of chemicals or contaminants being transported or stored in various components of the water balance. Water balances and chemical mass loads for the Zortman Mine (Spectrum 2000a) and the Landusky Mine (Spectrum 2000b) were conducted to assist in making decisions on the best use of reclamation resources to produce the maximum environmental benefits.

Estimates of the hydrologic regime at the Zortman and Landusky Mines have been made in several previous studies. The FEIS used HELP modeling to estimate then current water and contaminant loads from mine facilities, and then predicted future loads under various reclamation scenarios. The Groundwater Study (WMCI, pp. 172-173) made estimates of evapotranspiration for each mine facility, and estimated runoff and infiltration using generalized methods or the results of the FEIS. WMCI provided a water balance of the area on a drainage-by-drainage basis for existing conditions. Most of the previous studies used precipitation data collected at the mines. However, the key estimates of evapotranspiration, surface runoff and infiltration to groundwater were not made using on-site data. These were generalized from other basins, studies, literature sources and the HELP modeling.

This water balance is based on observations from 1997, 1998, and 1999. The average annual precipitation for these years was 22.35 inches, while the average annual precipitation over the past thirty years is about 19 inches, depending on the source cited. Maximum annual precipitation for the past thirty years is 29.23 inches and the minimum annual is 10.74 inches.

The water balances rely on daily pumping records of the volume of water captured at the seepage capture systems. These systems allowed entire waste rock dumps and dikes to be evaluated as huge lysimeters, enabling direct estimates of on-site groundwater recharge and evapotranspiration. Weekly water level readings in leach pad sumps enabled water balances to be calculated for many of the pads, which also effectively are huge lysimeters. Surface runoff and groundwater recharge rates were developed for the principle facilities and land cover types. A water balance equation was applied to all basins given the average precipitation over the mine areas.

A large database of laboratory water quality results was created and monitoring locations that best represented each of the mining facilities were selected. Average concentrations at each monitoring station were converted to contaminant loads to groundwater by application of the water balance results. The procedures and limitations of the water balance and mass loading evaluations are described in Spectrum (2000a and 2000b). Additional information can be found in HSI and Gallagher (2001).

### **Zortman Mine Water Balance**

An average steady state water balance, based on data from 1997, 1998 and 1999, and checked with flows through the water treatment plant, was calculated for the Zortman Mine. Records from the Zortman water treatment plant were used to estimate the amounts of captured and uncaptured water leaving the mine site

(HSI and Gallagher 2001). Rates of groundwater recharge were calculated based on direct volumetric analysis of the capture systems and leach pads. Infiltration rates (as percent of precipitation) calculated for unreclaimed leach pads, pits, and reclaimed leach pads and rock dumps are 70.5%, 56% and 45%, respectively. These rates are significantly greater than previous evaluations contained in the FEIS and the Groundwater Study. Rates for regraded-topsoiled areas, undisturbed areas and hard-surfaced areas (e.g. roads) are 45%, 33% and 30%, respectively.

The water balance indicated that of the total precipitation input (22.35 inches), the rate of evapotranspiration is 47.9%, infiltration is 44.3% and surface runoff is 7.8%. Of the infiltration component, 10.0% is recharge to leach pads, which is routed to the Goslin Flats LAD, 27.2% enters the capture systems and is sent to the Zortman Mine water treatment plant, 3.8% is off-site groundwater flow, and 3.3% is increased groundwater in storage and/or residual error of the method. Of the surface runoff, 5.2% enters the capture systems, and 2.6% runs off-site. Groundwater monitoring from the early 1990s through present has shown a net increase in the groundwater level within the Zortman Mine shear zones of about eight feet per year, leveling off in 2000. This suggests that with unreclaimed conditions, average precipitation and recharge rates may be greater and/or evapotranspiration rates lower than estimated in the steady state water balance.

Results of the Zortman Mine water balance support the conclusion that the vast majority of groundwater flow leaves the mine as shallow discharge to the capture systems. A very small amount of groundwater (about 3 gpm) from the mine enters the tributaries of Lodgepole Creek. Details regarding the assumptions and limitations of the water balance methodology are provided in HSI and Gallagher (2001).

### **Landusky Mine Water Balance**

A more complicated groundwater flow system is evident at the Landusky Mine. Unlike at the Zortman Mine, surface water basins could not be used as the basic watershed unit. Groundwater basins were defined for each capture system, based on site geology, premining topography, the potentiometric surface map, and annual volume of water reporting to each discharge point. Flow records from the Landusky Mine water treatment plant were used to estimate the amount of captured and uncaptured water leaving the mine site (HSI and Gallagher 2001). Rates of groundwater recharge were calculated based on direct volumetric analysis of the capture systems and leach pads. Infiltration rates (as percent of precipitation) calculated for unreclaimed leach pads and pits, and reclaimed leach pads and rock dumps were 69%, 62% and 48.6%, respectively. These rates are significantly greater than previous evaluations contained in the FEIS and the Groundwater Study. A lower rate of 31.1% was obtained for the Mill Gulch waste rock dump due to the use of geosynthetic and clay liners in the existing reclamation cover. Rates for regraded-soiled areas, undisturbed areas and hard-surfaced areas (e.g. roads), were 48.6%, 24.5% and 37%, respectively.

The water balance for the Landusky Mine was performed for 1998 due to the availability of consistent data and 1998 being a more typical year for precipitation. The water balance predicted that of the total 1998 precipitation input (23.33 inches), the rate of evapotranspiration was 54.9%, infiltration was 43.0% and

surface runoff was 2.1%. Of the infiltration component, 12.6% is recharge to leach pads, which is routed to the Goslin Flats LAD, 23.1% enters the capture systems and is sent to the Landusky Mine water treatment plant, and 7.3% is off-site groundwater discharge. Of the surface runoff, 0.5% enters the capture systems or leach pads, and 1.6% runs off-site.

The Landusky Mine water balance (Spectrum 2000b) shows total groundwater capture of 208 million gallons, versus 211.6 million gallons measured in 1998, a difference of 1.68%. The match by drainage basin is more variable. Details of the assumptions and limitations of the water balance methodology are provided in HSI and Gallagher (2001).

Monitoring well data within the Landusky Mine pit/shear zone area indicate that groundwater levels have risen by as much as 66 feet since the early 1990s (well ZL-206). The rising levels have resulted in formation of the August pit lake and suspected additional seepage to Swift Gulch. This indicates that with unreclaimed conditions, average precipitation and recharge rates may be greater and/or evaporation rates lower than estimated in the steady state water balance.

Discharge from artesian well WS-3 was not included in the 1998 Landusky Mine water balance estimate. When flowing freely, it has the potential to capture an additional 75-150 million gallons per year. Based on monitoring during the aquifer tests, groundwater supplying WS-3 is derived principally from the shear zone, the diversion of water from other discharges such as the August drain and Gold Bug adit, and the area of syenite aquifer on the east side of the Landusky Mine.

The Landusky Mine water balance and monitoring data support the conclusion that the vast majority of groundwater flow leaves the Landusky Mine area as shallow groundwater discharge to the capture systems, Gold Bug adit, August drain, artesian well WS-3 (when flowing), and springs and seepage in Swift Gulch. Details regarding the assumptions and limitations of the water balance methodology are provided in HSI and Gallagher (2001).

### **Uncaptured Flow**

There are a number of methods which may be used to estimate the amount of surface water and groundwater not being captured at the mines, including estimation from direct observations, physical hydrology, and chemical hydrology. This is of interest in evaluating the effectiveness of the current capture systems and whether the reclamation alternatives will vary in their influence on future effectiveness.

The water balance and chemical mass loading reports (Spectrum 2000a and 2000b) use physical hydrology (water table contour maps and hydraulic conductivity) to estimate the amount of groundwater leaving the mine site outside the drainages with capture systems. It assumes that all groundwater in drainages with capture systems is captured. The results of a second technique using a chemical mass balance approach are shown in Chapter 4 and provide estimates of uncaptured flows within all principal drainages, including those with capture systems. This approach is presented in Section 4.3.1, and details are provided in a

project report by Robertson (2000d). These two techniques rely on independent data sources and the results are different. There is a large inherent component of variability and uncertainty in all hydrology data, so the differing results should be viewed as being within the range of probable outcomes.

*Zortman Mine:* The water balance demonstrates that 52.1% of the precipitation becomes surface water runoff or groundwater recharge. On a mean annual basis over the mine site, this is equivalent to 313 gpm. Of the total surface water and groundwater, about 59 gpm (18.5%) is uncaptured. This includes water moving off undisturbed areas. About 20 gpm (6.4%) of this flows to the southern drainages, Ruby, Alder and Carter Gulches, and 3.1 gpm (1%) to Lodgepole Creek. The remainder, equivalent to about 34 gpm (11.1%), is not accounted for in the water balance. It represents the combination of inherent error and the increase in groundwater storage within the mine site. As noted above, groundwater levels in the Zortman Mine pit area have been rising since the early 1990s.

The chemical mass balance method gives uncaptured flow rates in Zortman Mine drainages of 0.03 gpm in Alder Spur, 1.8 gpm in Carter Gulch, 11.6 gpm in Ruby Gulch, and 0.06 gpm in Lodgepole Creek. The combined uncaptured flow to the south totals 13.4 gpm. The purpose and methods of the chemical mass balance are different from the water balance approach described above, but from the overall hydrologic perspective, the results from the two methods are reasonably consistent.

*Landusky Mine:* Uncaptured flows from the mine area to King Creek and Swift Gulch are estimated in two ways in the water balance report: actual measurements and application of the water balance equation. The average discharge from the mine area, based on the average for 24 measurements at station L-19 from 1997 through 1999, is 25 gpm. The averages from the measured flows are less than those predicted by the water balance method and are greater than those predicted by the chemical mass load method described below. The water balance demonstrates that 45.1% of the precipitation becomes surface water runoff or groundwater recharge. On a mean annual basis, this is equivalent to 779 gpm. Of the total surface water and groundwater derived from the mine, about 163 gpm (19.9%) is uncaptured. This includes water moving off undisturbed areas. About 48.7 gpm (6.3%) flows from the mine area to Swift Gulch, 29.2 gpm (3.7%) to King Creek, and 76.7 gpm (9.9%) represents the combination of inherent error, uncaptured flow to the south, and increases in groundwater storage.

The chemical mass balance method gives uncaptured flow rates in Landusky Mine drainages of 8.7 gpm in Swift Gulch, 9.65 gpm in King Creek, 0.35 gpm in Sullivan Gulch, 12.1 gpm in Mill Gulch, and 37.5 gpm in Montana Gulch. The combined uncaptured flow to the south totals 49.9 gpm. As with the Zortman Mine results, the purpose and methods of the chemical mass balance for the Landusky Mine are different from the water balance approach, but from the overall hydrologic perspective, the results from the two methods are reasonably consistent.

These estimates of uncaptured flow are based on the groundwater flow conditions prevailing through 1999. Since that time, the artesian well WS-3 has been allowed to flow to control water levels beneath the Landusky pit complex. When WS-3 is flowing, it significantly expands the area of captured groundwater

beneath the pit complex and into the Swift Gulch drainage. WS-3 water is routed to the Landusky Water Treatment Plant. The effect of WS-3 is to capture an additional estimated 33 to 45 gpm, compared to pre-mining conditions. Discussion of the effect of WS-3 is discussed further in Section 3.3.9.

### **Chemical Mass Loading Evaluation**

Chemical mass loading models of both mines were developed to estimate the total loads of contaminants generated by all mine facilities and to evaluate the ultimate fate of the contaminants. Based on the mines' subbasins and the water balance, contaminant fate was split among that going to the water treatment plant, to the LAD, and to groundwater. Average annual loads of total dissolved solids, acidity, sulfate, nitrate (nitrite plus nitrate), arsenic, selenium and seven cationic metals were calculated. The results demonstrate that the principal sources of mine-related contaminants and their fate can be accounted for. The results are best interpreted by comparison of relative loading rates among the mine facilities. The procedures and limitations of the chemical mass loading evaluations are provided in Spectrum (2000a and 2000b).

#### **Zortman Mine Chemical Mass Loading**

Results of the chemical mass loading model indicate that about 32% of the total sulfate load is generated by the Z85/86 leach pad. The Alder Gulch waste rock dump, O.K. waste rock dump, plant process area, and Ruby pit each generate from 5 to 10% of the total sulfate load. In terms of loads per unit area, the Z85/86 leach pad is the strongest source. The O.K. waste rock dump and the rest of the leach pads are the next strongest sources.

Total metals load is the sum of aluminum, cadmium, chromium, copper, iron, lead, manganese, nickel and zinc. As with sulfate, the total metals load is greatest from the Z85/86 leach pad, comprising nearly 22% of the total metals load from the mine. The Alder Gulch waste rock dump and Ruby pit contribute about 11 and 10%, respectively, of the mine's total metals load. Most of the areas high in sulfate load are also high in metals load. On a load per unit area basis, the Z85/86 leach pad ranks as the strongest source. The Z82 leach pad, O.K. waste rock dump, and the pits are the next strongest sources. The average concentration of arsenic is greatest in the Z82 leach pad effluent (4.2 ppm). The Z82 leach pad was removed in 2001 as part of interim reclamation. All of the pit-area groundwater has elevated arsenic at concentrations above the chronic aquatic life standard of 0.15 ppm.

Selenium concentrations at all Zortman Mine facilities are relatively low. The highest average concentration is found in the Z83 leach pad (0.064 ppm). This is the only Zortman Mine facility at which selenium exceeds the drinking water quality standard of 0.05 ppm.

The sources and fate of the Zortman Mine sulfate and metals loads are determined from the water balance and are shown in Figures 3.3-12 and 3.3-13. They indicate that 78% of the total metals load and 66% of the sulfate load is captured and routed to the Zortman water treatment plant. The Goslin Flats LAD

receives 18% and 31% of the metals and sulfate loads, respectively. The total metals and sulfate loads entering groundwater that are not captured is estimated at 4% and 3%, respectively.

### **Landusky Mine Chemical Mass Loading**

The difference between the surface water and groundwater basins at the Landusky Mine is much more pronounced than at the Zortman Mine. The Landusky Mine chemical mass loading estimates were developed using the groundwater basins discussed previously.

The chemical mass loading results indicate that the L87 and L91 leach pads produce the greatest overall and the greatest per-unit-area loading rate of sulfate. The next largest total sulfate loads are derived from the upper Montana Gulch capture system, lower Montana Gulch capture system, Gold Bug adit, and Sullivan Gulch capture system, respectively.

The Gold Bug adit discharge has the greatest overall loading rate of total metals, followed by Sullivan Gulch and upper Montana Gulch. On a per unit area basis, the L84 and L83 leach pads rank first and second in total metals production, followed by the Gold Bug adit discharge and Sullivan Gulch. The average concentration of arsenic is greatest in the Gold Bug adit discharge (0.42 mg/l). It is also above chronic aquatic standards, as are waters from the L79-82, and L85/86 leach pads.

Selenium concentrations are highest in the L87 and L91 leach pads (1.04 and 1.05 mg/l, respectively) and above the chronic aquatic standards in all other leach pads and the capture systems in Sullivan Gulch, Mill Gulch and upper Montana Gulch.

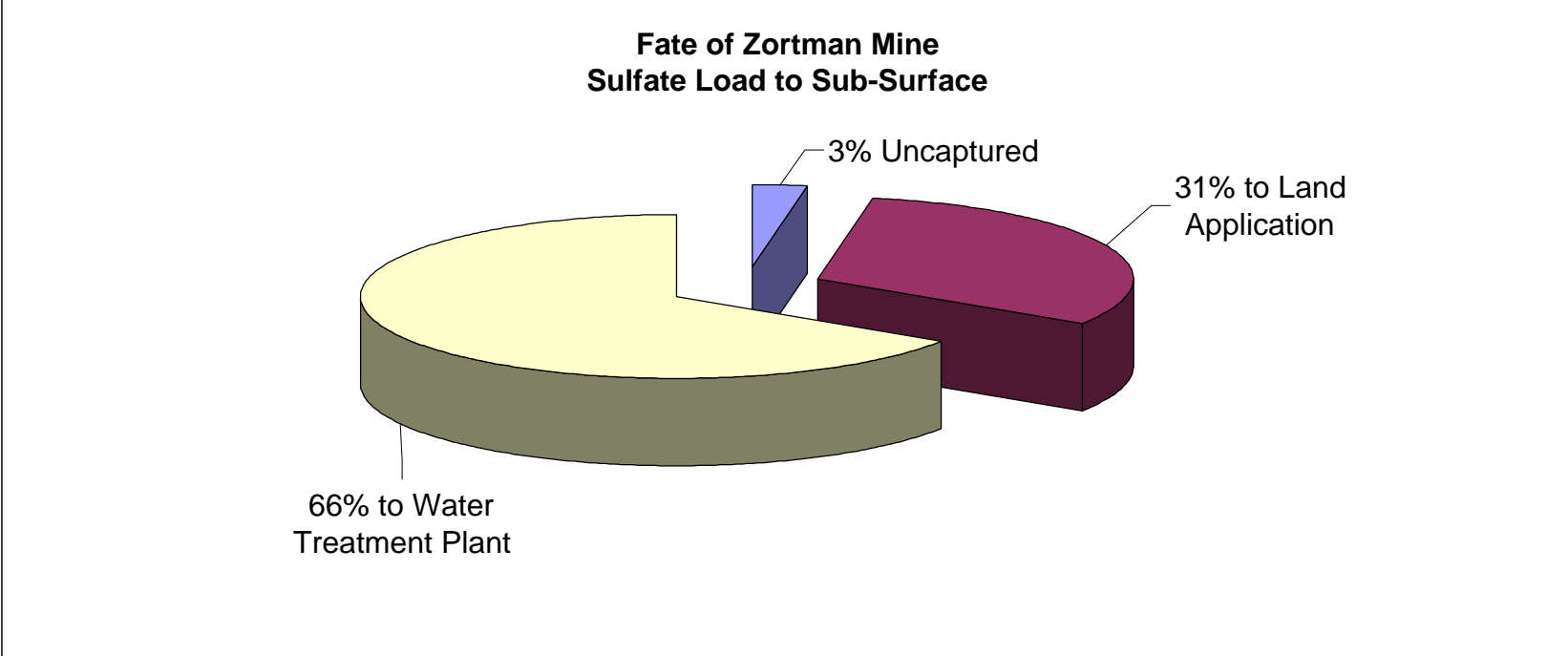
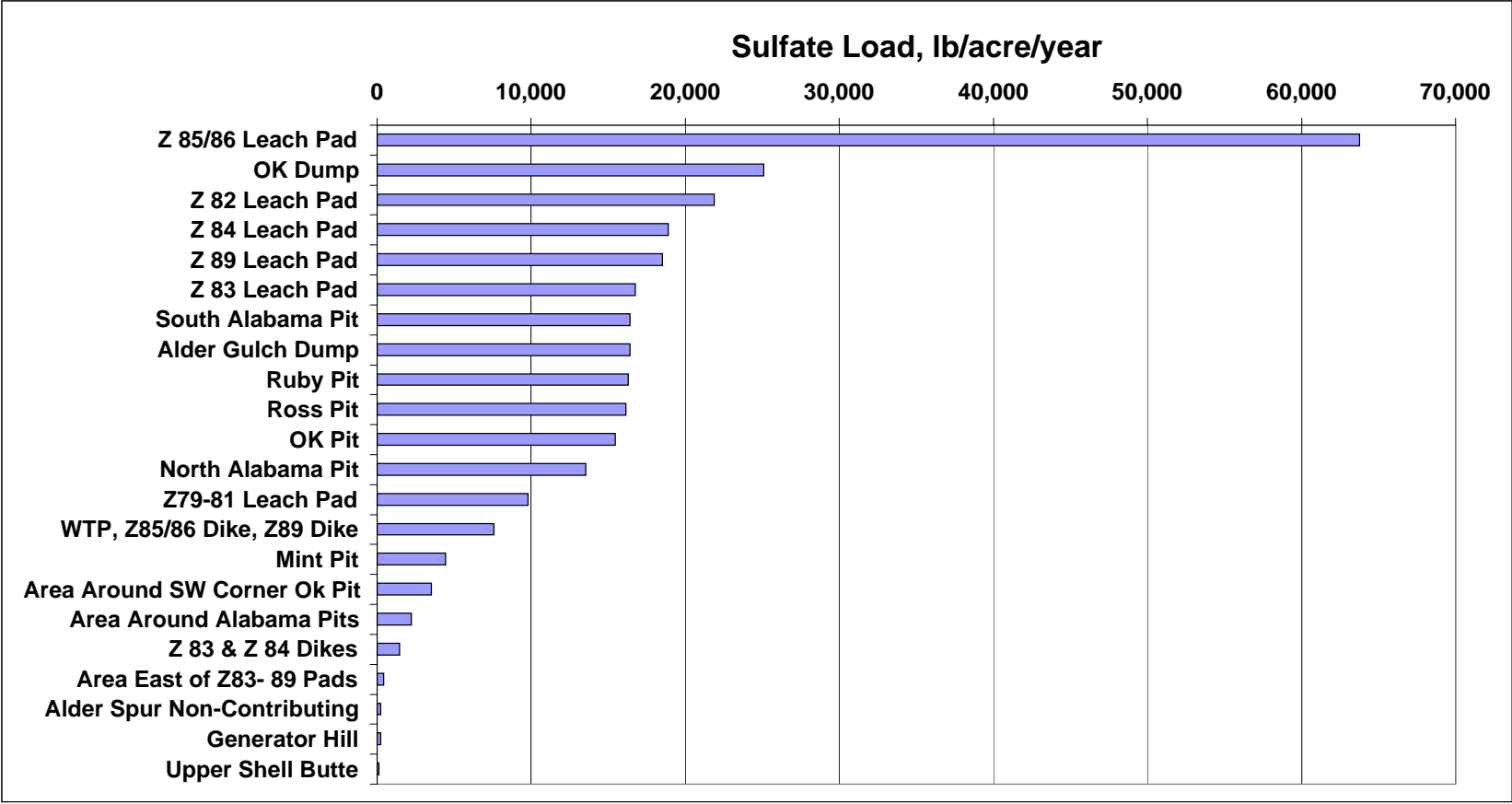
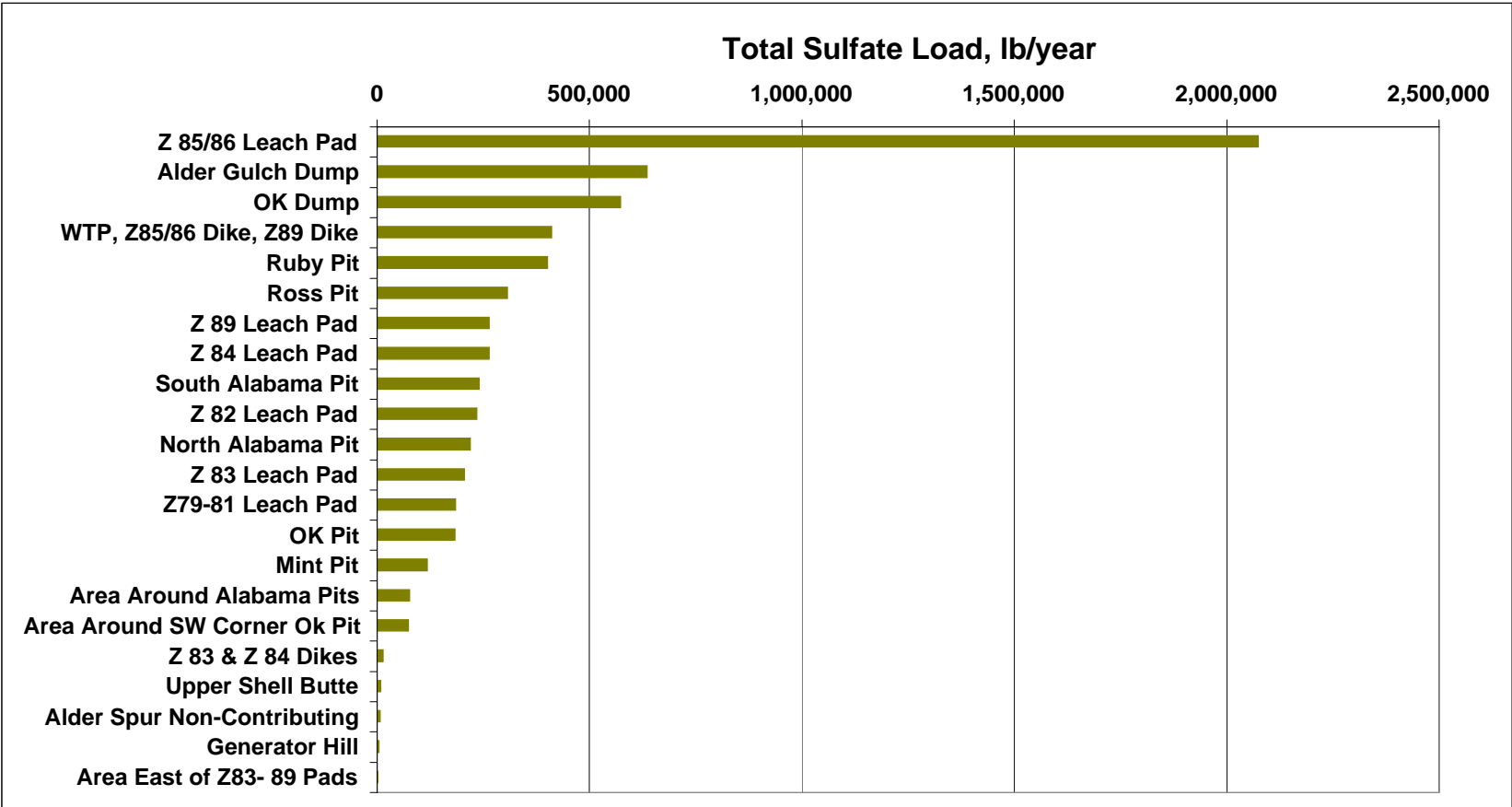
The sources and fate of the Landusky Mine sulfate and metals loads are determined from the water balance and are shown in Figures 3.3-14 and 3.3-15. The sulfate distribution indicates that 66% is collected from the leach pads and routed to the LAD area, 24% enters the capture systems and goes to the water treatment plant, 9% is surface water discharge (primarily lower Montana Gulch), and 1% is uncaptured groundwater. Of the total subsurface metals load, all but 2 to 3% enter the capture systems or leach pads.

The continuing discharge of artesian well WS-3 pre-dates the chemical mass load analysis, and although its load is not specifically accounted for in the analysis, all discharge is routed to the Landusky water treatment plant. WS-3 diverts a portion of the flows and corresponding loads from the Gold Bug Adit, the Upper Montana Gulch capture system and Swift Gulch (HSI and Gallagher, 2001).

### **Comparisons Between Zortman and Landusky Mines**

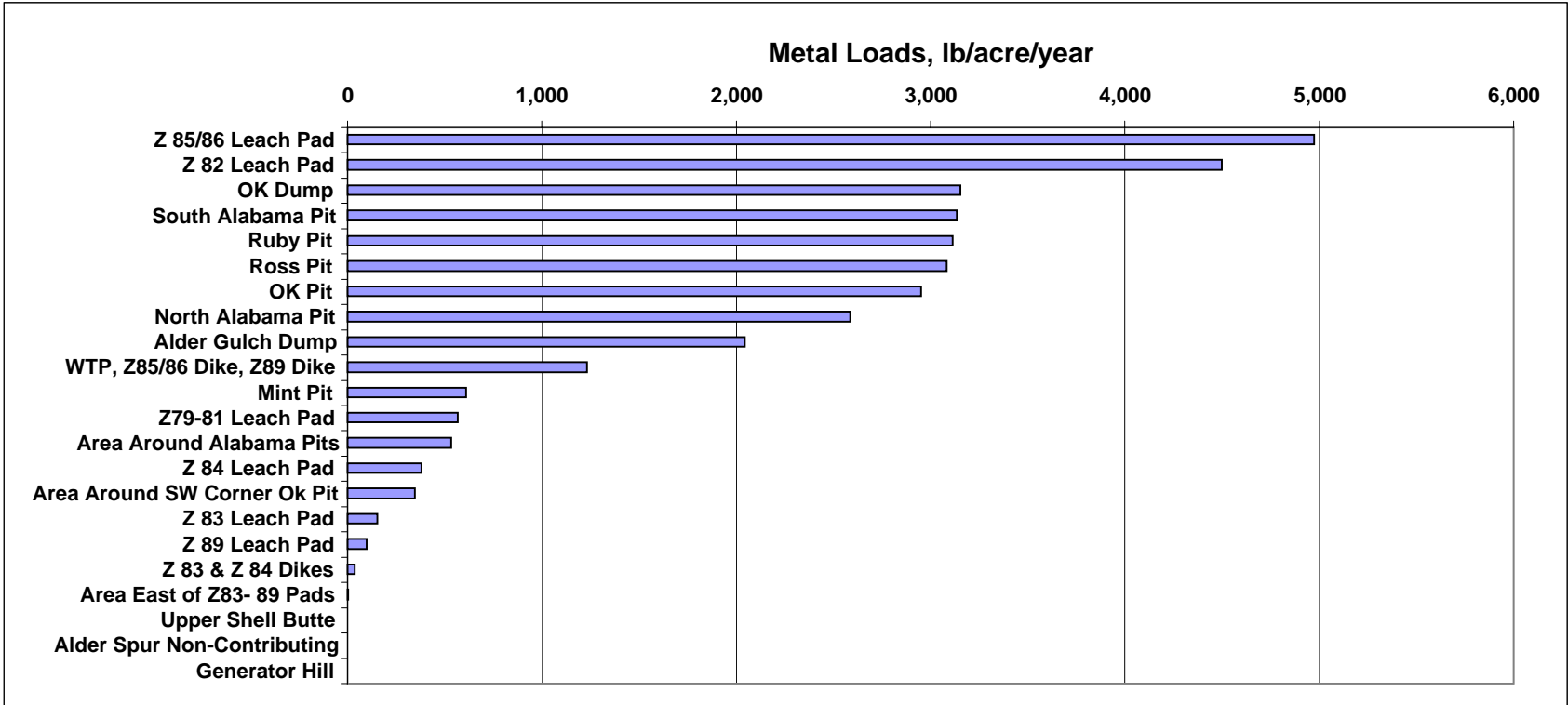
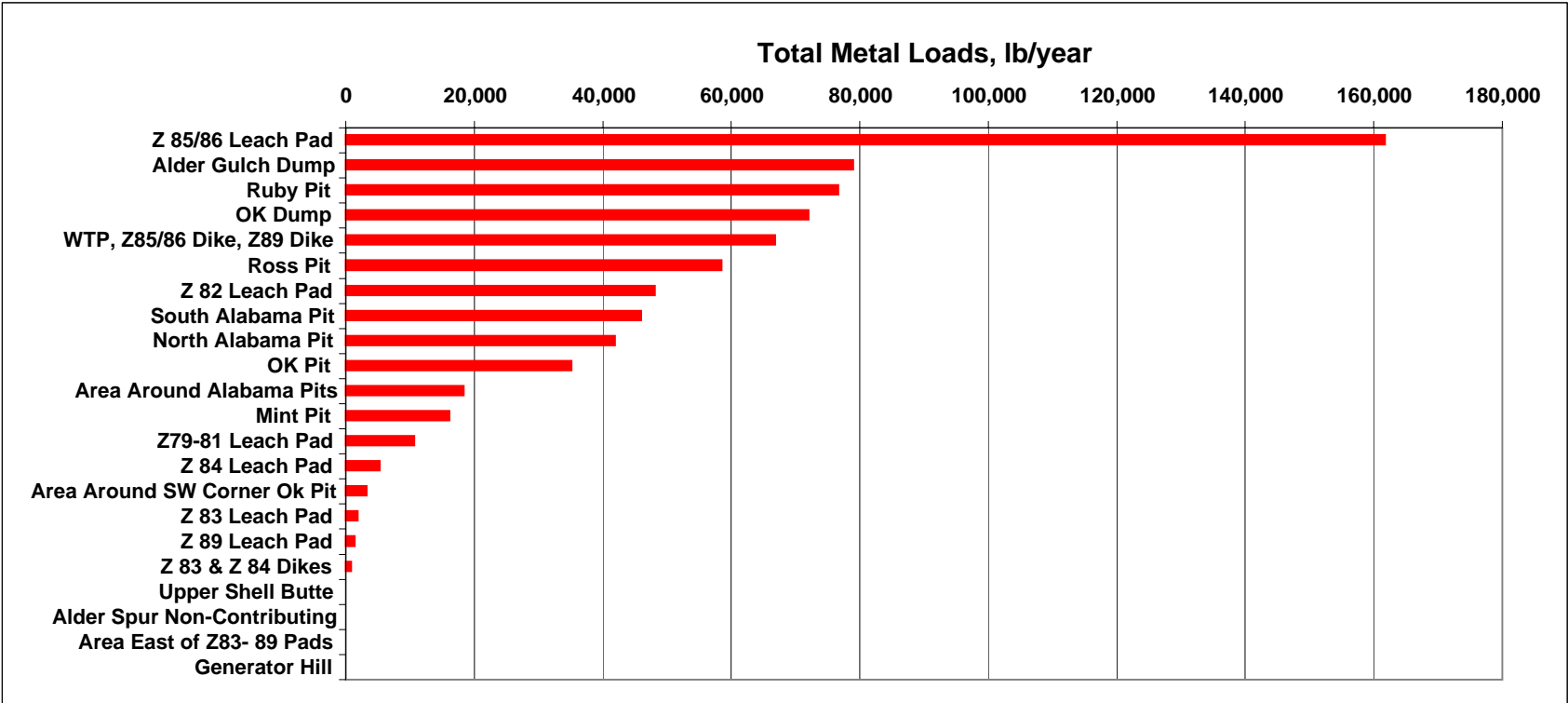
Water balances for the two mines show that the annual volume of groundwater discharge from the Landusky Mine is approximately 2.8 times greater than at the Zortman Mine. However, the contaminant loads are not always proportional to the amount of groundwater. In comparing the contaminant loads at the two mines, the Zortman Mine has the greatest loads of arsenic, iron, manganese, and sum of cationic metals; and the Landusky Mine has the greatest loads of nitrate and selenium.

Sources and Fate of Zortman Mine Annual Sulfate Loads

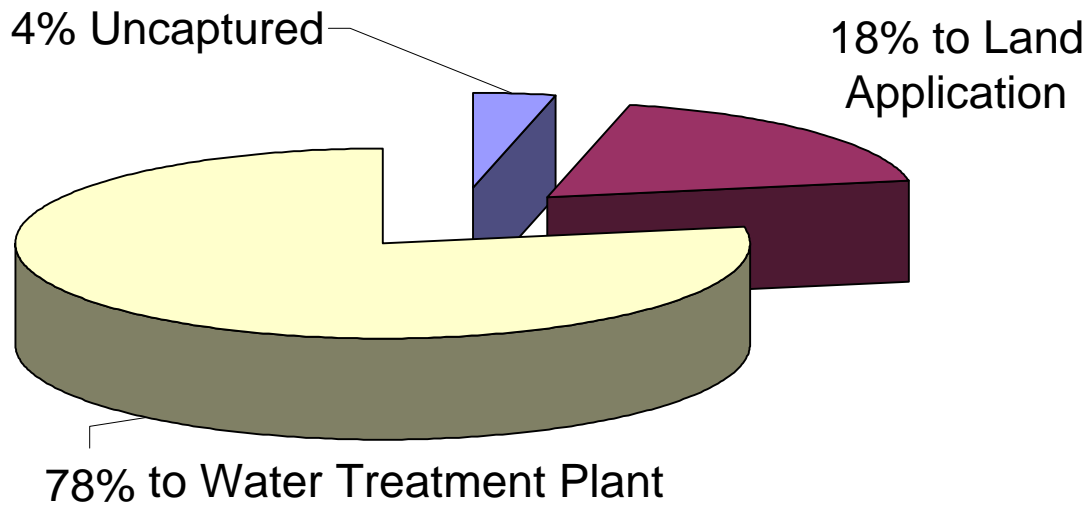


SOURCE: SPECTRUM , 2000e

Sources and Fate of Zortman Mine Annual Total Metal Loads

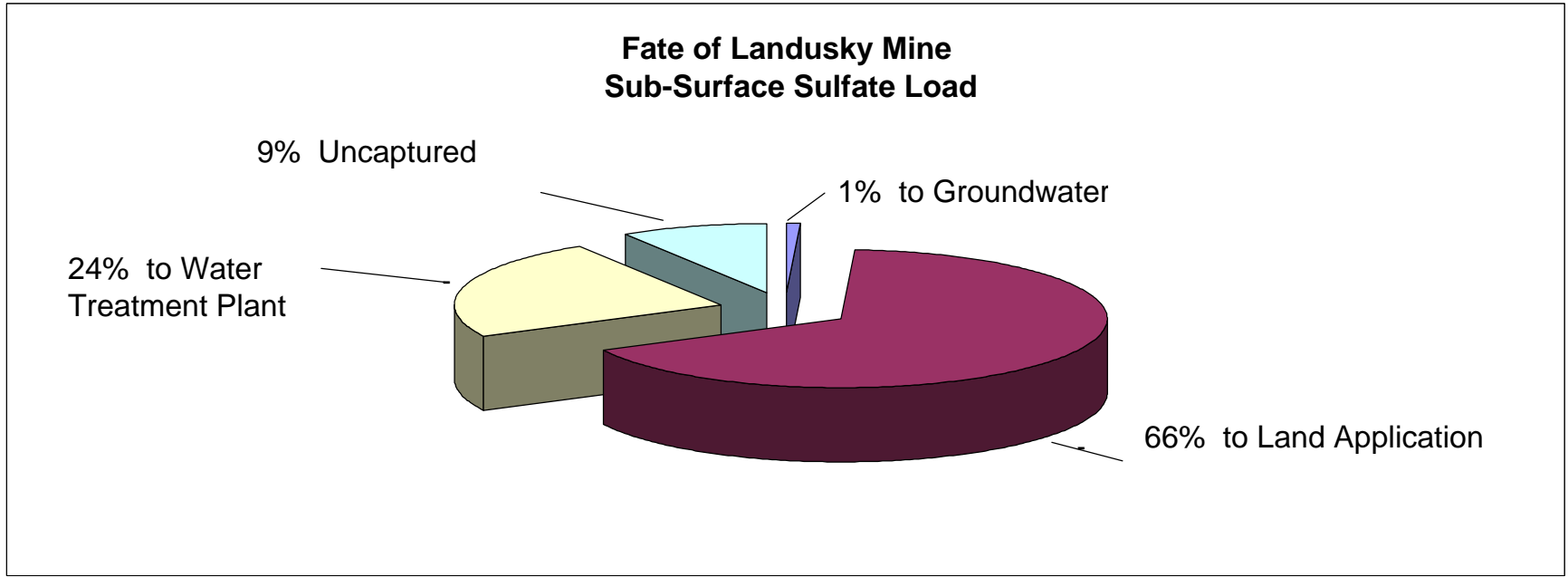
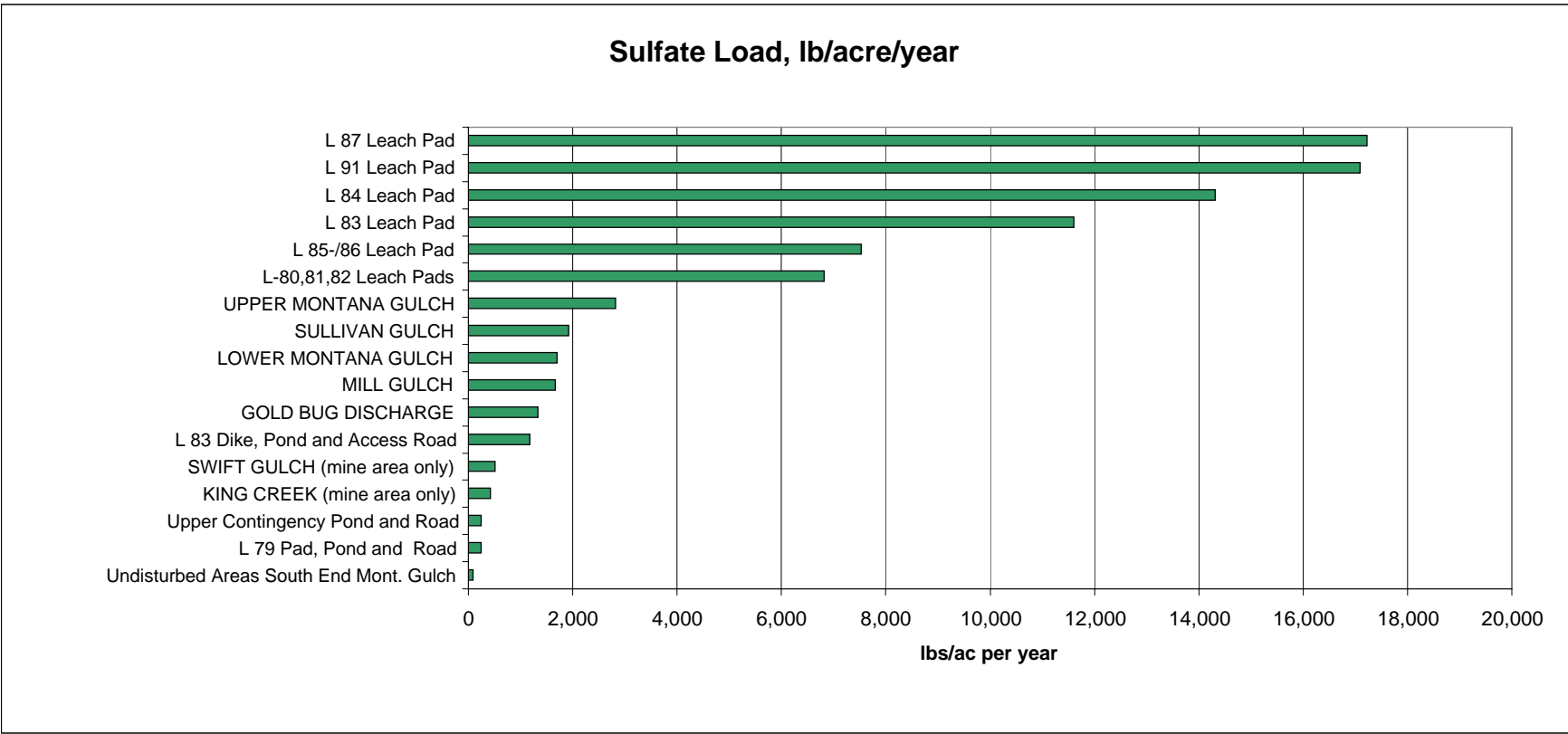
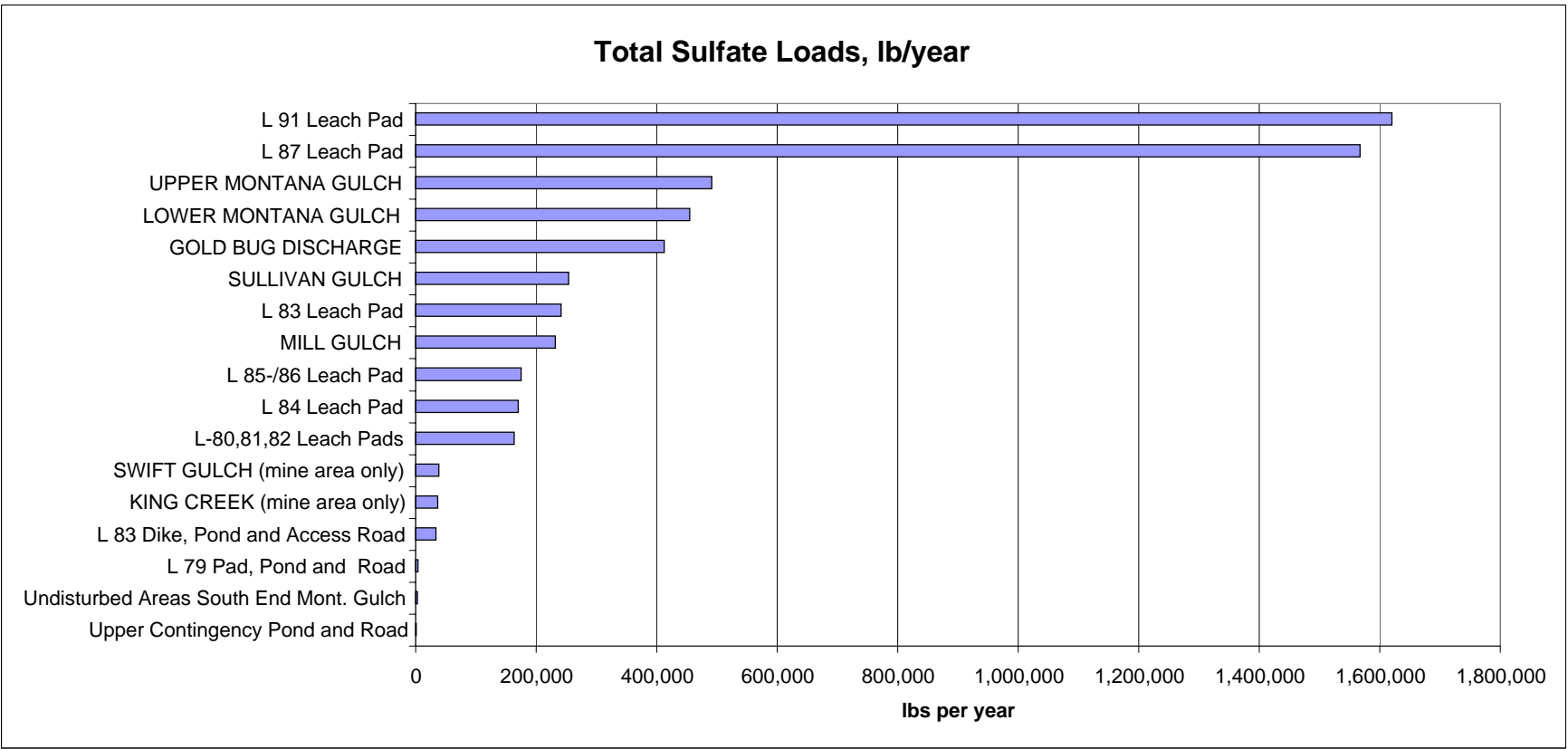


Fate of Zortman Mine  
Metals Load to Sub-Surface



SOURCE: SPECTRUM 2000e

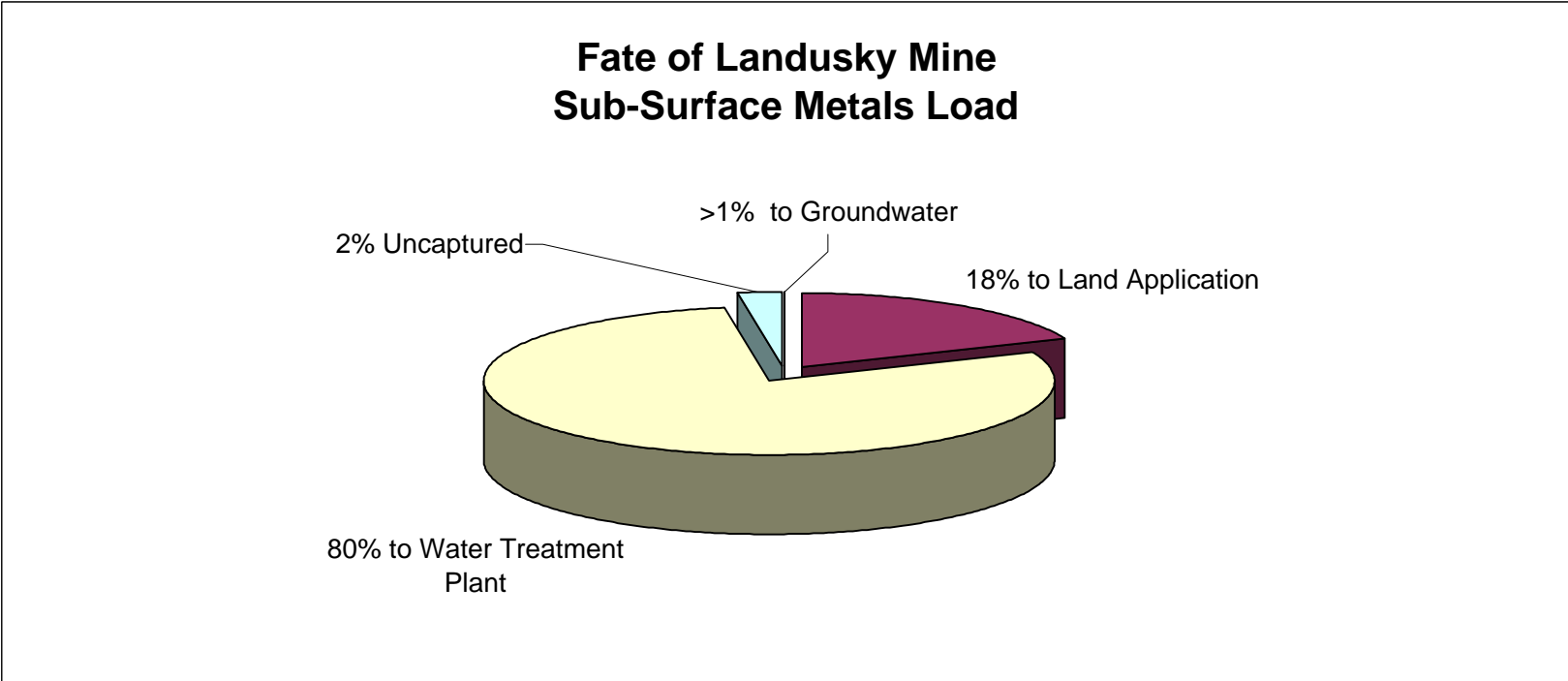
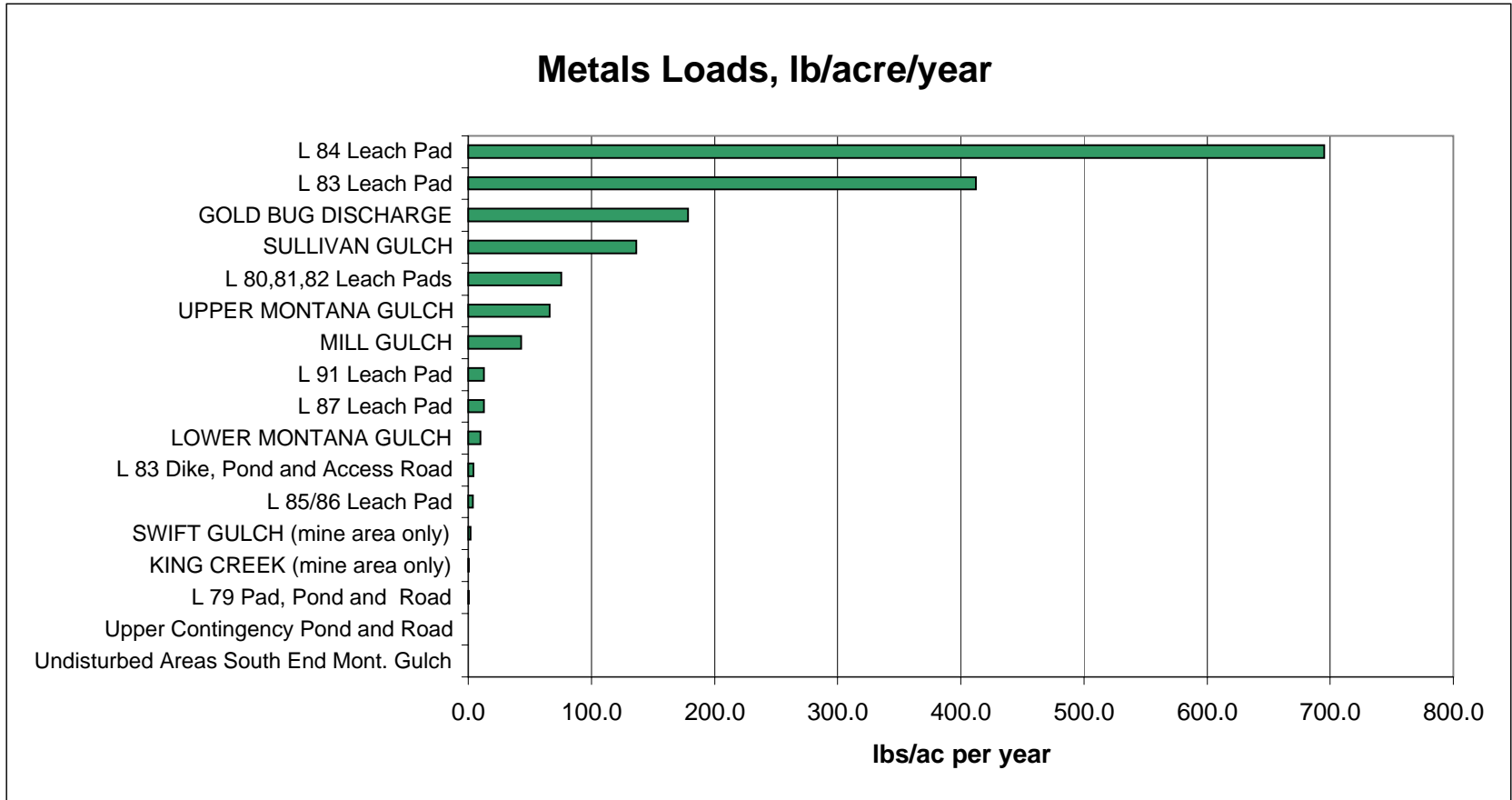
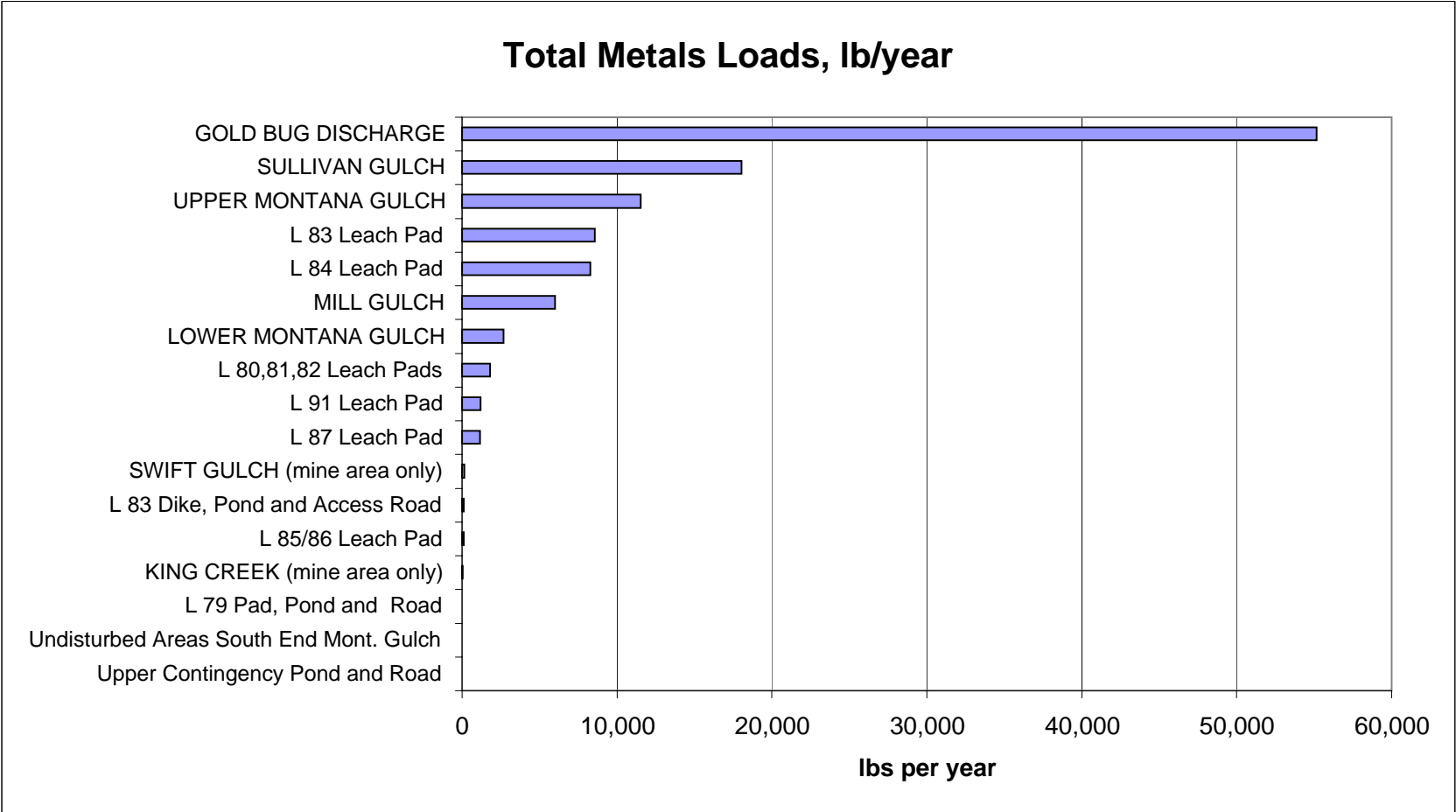
Sources and Fate of Landusky Mine Annual Sulfate Loads



SOURCE: SPECTRUM ENGINEERING, 2000f

FIGURE 3.3-14

Sources and Fate of Landusky Mine Annual Total Metal Loads



SOURCE: SPECTRUM ENGINEERING, 2000f

In general, contaminants are more concentrated at the Zortman Mine than at the Landusky Mine. The principle sources of nitrate and selenium at the Landusky Mine are the L87 and the L91 leach pads. The two mines are similar in their annual loads of total dissolved solids. Groundwater acidity data indicates that the acidity load at the Zortman Mine is approximately ten times greater, in spite of the nearly three times smaller total groundwater discharge. This is probably due to the greater exposure of sulfides to weathering processes and the more advanced state of geochemical evolution at the Zortman Mine. The pH of surface soils, as measured during reclamation activities, indicates a greater proportion of samples with a pH of less than 4.5 s.u. at the Zortman Mine. A large network of mine workings at the Zortman Mine lying just above the baseline water table become saturated during higher water table conditions and flush oxidation products to the capture systems. At the Landusky Mine, more of the underground workings appear to lie beneath the water table during all seasons, minimizing the degree of oxidation and flushing events.

Although the present-day concentrations of most contaminants are greater at the Zortman Mine, contaminant production from the Landusky Mine is going to increase over time to greater levels than at the Zortman Mine. The Landusky Mine has additional neutralization potential, given the presence of the Emerson shale and other carbonate rocks; however, once that is ‘swept’ out of the system, water quality (in particular metals and sulfate) at the Landusky Mine would become similar to the Zortman Mine today.

This could take from tens to hundreds of years. Additionally, the volume of potentially reactive rock material at the Landusky Mine, in particular on the L87/91 leach pad, represents a large storage of potential contamination. Since the material on the L87/91 leach pad is on a lined area, it can be contained, treated and disposed of easier than material in the waste rock dumps or pit areas.

### **Calculation of Stored Oxidation Products**

There is a significantly larger mass of potential contaminants in storage at the Landusky Mine than at the Zortman Mine. With the exception of iron, this is largely a reflection of the volume of material present in the L87 and L91 leach pads. Therefore, although the present contaminant concentrations and loads at the Zortman Mine exceed those at the Landusky Mine, there is a larger volume of soluble contaminants at the Landusky Mine.

A “stored product inventory” was conducted to estimate the volume of potential contaminants in each mine facility. This is an accounting of the potential storage of secondary minerals formed as a result of sulfide oxidation and, if alkali minerals are present, subsequent acid neutralization. These secondary minerals are typically soluble in rainwater and are a secondary source of sulfuric acid ( $\text{H}_2\text{SO}_4$ ) and metals (copper, cadmium, nickel, zinc, etc.). The stored product inventory calculated for each of the subbasins for sulfate, arsenic, selenium and seven cationic metals, show that the oxidation/neutralization and mineral precipitation reactions that have occurred at the surface to date have produced a significant stored product inventory.

The calculated sulfate load reporting to the Landusky Mine water treatment plant is approximately 2 million pounds per year. Comparing this value with the estimated 202 million pounds of sulfate currently stored in

the Landusky Mine heaps and waste rock leads to the generalization that if all sulfide oxidation processes could be shut down on the site today and the only ongoing source of contamination was from the solubilization of current stored products, water treatment would need to continue for about 100 years to treat the estimated storage. If the total amount of sulfate to the LAD, groundwater and the water treatment plant is considered, the stored contaminant inventory at the Landusky Mine would require about 34 years to remove at the rates of water recharge that occurred in 2000.

### **3.3.5 Water Quality Classification System**

#### **Previous Classifications**

One of the primary goals of the SEIS is to evaluate the current extent and magnitude of mining-related impacts to groundwater and surface waters in and around the mines. A consistent and comprehensive assessment is difficult, given the geologic and hydrologic complexity of these sites. A water quality classification evaluation of mine waters, using common ions, was previously attempted by WMCI (p. 204). Their focus was to describe water quality associated with the principal hydrogeologic environments at the mine sites on a drainage-by-drainage basis.

#### **New Classification System**

While the WMCI analysis was thorough on a drainage-by-drainage basis, it did not attempt to distill the extensive amount of information into a site-wide summary defining the extent and type of mining-related impacts. Subsequent evaluation found that treatment of water quality data on a drainage basis blurs the distinctions that can often be found for specific rock types. In addition, common ion chemistry is not particularly useful in distinguishing between natural waters and impacted waters. Review of the historic and recent water quality data, along with the literature on ARD, revealed that the following parameters are generally definitive of mining impacts:

- Elevated specific conductance, due to enhanced mineral dissolution in ARD,
- Acidic pH, due to pyrite oxidation reactions that produce hydrogen ions,
- Elevated nitrate nitrogen, due to explosives residuals, and fertilizer on reclaimed areas,
- Elevated heavy metals cadmium, copper, nickel and zinc, due to increased solubility with lower pH,
- Elevated sulfate, a byproduct of pyrite oxidation,
- Little to no alkalinity, due to exhaustion by the acidity produced in ARD, and
- Cyanide above 0.01 mg/l, indicating impacts from gold processing chemicals.

Groundwater and surface water baseflow in some locales is affected by natural mineralization. This can make it difficult to distinguish mineralized natural waters from mining impacts. In order to address this issue, data from naturally mineralized areas was compared to known mine impacts. A data set of 36 samples from Swift Gulch was compiled from 1996 to 2000, which contains samples of natural springs, seeps and surface waters within the Surprise and Gold Bug shear zones. These samples were collected from both the south (mine side)

and north (unmined) sides of Swift Gulch. The stations sampled are representative of shallow groundwater and surface water baseflow in the syenite porphyry aquifer. The results of these analyses allow differentiation of the following water types and characteristics:

- A “Headwaters” type characterized by very low dissolved solids, low alkalinity, pH of 6 to 7 s.u., and very low metals concentrations (excepting iron).
- A “Mineralized Background” type for the syenite aquifer characterized by specific conductance less than 1,000 uS, pH greater than 6.8 s.u., sulfate of 75 to 400 mg/l, iron greater than 0.3 mg/l and arsenic greater than 0.1 mg/l, very low nitrate and very low cadmium, copper, nickel and zinc concentrations.
- An “ARD/Mining Impacted” type characterized by specific conductance greater than 1,000 uS, pH generally in the range of 4 to 6 s.u., sulfate generally greater than 800 mg/l, little to no alkalinity, and elevated nitrate and metals concentrations.

Evaluation of hundreds of water quality samples from both mine sites revealed four other water types in addition to those above:

- “Non-Mineralized” type,
- “Limestone Background” type,
- “Neutralized ARD” type, and
- “Various Mine-Related Indicators” type.

It was apparent that at any station, water quality could vary seasonally and in response to recharge and runoff events. Surface waters were more apt to be of mixed types. Based on these considerations, a water quality classification system for shallow groundwater and surface water base flow was developed as presented in Table 3.3-1. It is recognized that water quality at some stations is changing, and the water type classification could change. Stormwater runoff was not classified. The reader is referred to Sections 3.3.6 and 3.3.7 for drainage basin information on water quality trends at key stations. Additional information concerning the system, water quality database, and application of the system can be found in HSI and Gallagher (2001).

An entirely different water type exists for natural groundwater in the Goslin Flats LAD area due to the dominance of alluvium and shale bedrock as aquifer materials. A distinct classification was not developed for this location. The reader is referred to SEIS Section 3.3.6 (Goslin Gulch) and HSI and Gallagher (2001) for information on water quality trends.

**Table 3.3-1. Water Quality Classification System for Zortman Mine and Landusky Mine Water Samples**

Water Sample Classification Rules							
TYPE	1	2M	2NM	2L	3	4	5
Specific Conductance (uS)	< 250	250 - 1000	< 1000	500 - 1500	≥ 1000	≥ 1000	
pH ( s.u.)	6 - 8	≥ 6.8	≥ 6.8	≥ 7	≤ 6	≥ 6.8	
Nitrate (mg/l)	≤ 0.1	< 1.0	< 1.0	< 1.0	> 1.0	> 1.0	>1.0
Copper (mg/l)	< 0.05	< 0.05	< 0.05	< 0.05	≥ 0.1	< 0.05	> 0.05
Sulfate (mg/l)	2 - 20	75 - 400	75 - 400	SO <sub>4</sub> < HCO <sub>3</sub>	> 400	> 400	
Alkalinity (mg/l)	5 - 30	30 - 150	30 - 150	> 150	< 20	> 20	
Arsenic (mg/l)	≤ 0.01	> 0.10	< 0.10	< 0.10	< 0.10	< 0.10	> 0.10
Iron (mg/l)	≤ 0.5	≥ 0.3	0.01 - 1.0	< 0.1			
Cyanide (mg/l)	< 0.01	< 0.01	< 0.01	< 0.01			> 0.01

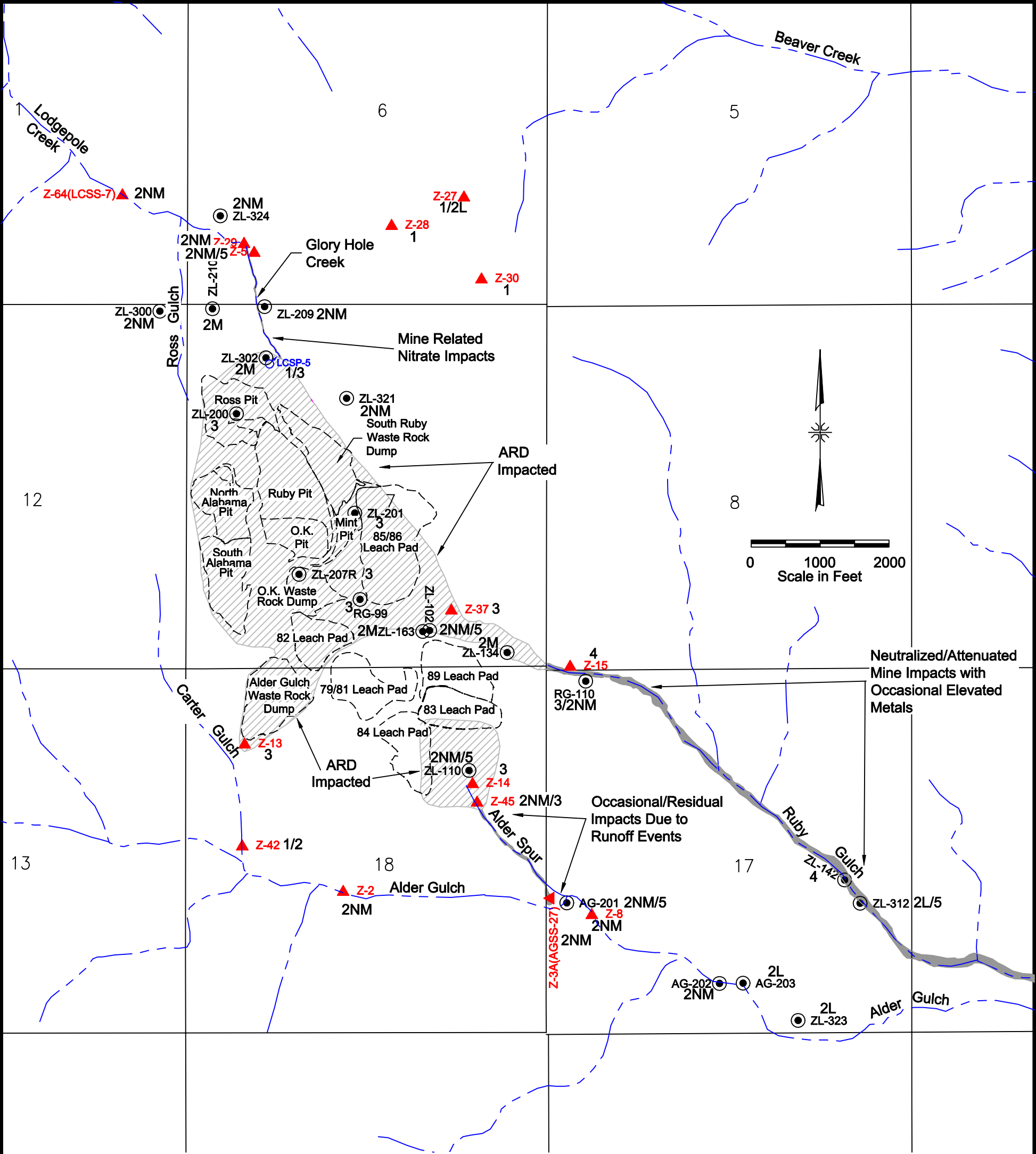
NOTES: 1 - Headwaters Background, Groundwater (GW) & Surface Water (SW)  
2M - Mineralized Syenite Background, GW & SW  
2 NM - Non-Mineralized Syenite Background, GW & SW  
2L - Limestone Background, GW  
3 - Mine/ARD Impacted, GW & SW  
4 - Neutralized ARD-Mixed, GW & SW  
5 - Various mine-related indicators at low levels or occasionally (nitrate, metals, cyanide), non-Type 4 Classification based on Swift Gulch Data, 1996-2000, adjusted for the observed ranges at other sites with pH and SC fixed. Any single parameter exceeding the type 5 criteria triggers the application of Type 5.

## **Water Classification Interpretations**

The classification system was applied to 764 samples collected from 104 monitoring stations in 1997 through 1999. The results are presented in Figures 3.3-16, 3.3-17 and 3.3-18. These figures are shaded to indicate the zones of Mine/ARD Impacted waters (Type 3), ARD Neutralized waters (Type 4) and Various Mine-Related Indicators (Type 5). Mine facility boundaries, groundwater basins and geologic boundaries were used to assist in defining the extent of mine impacted areas where data were limited. Areas under leach pads were not classified due to lack of information, except for the Z85/86 leach pad where ARD impacts in the underdrain are known. Groundwater in the unshaded areas in these figures has not been impacted by the mines, and the groundwater conditions would be the natural background. A table with individual monitoring station classifications can be found in HSI and Gallagher (2001).

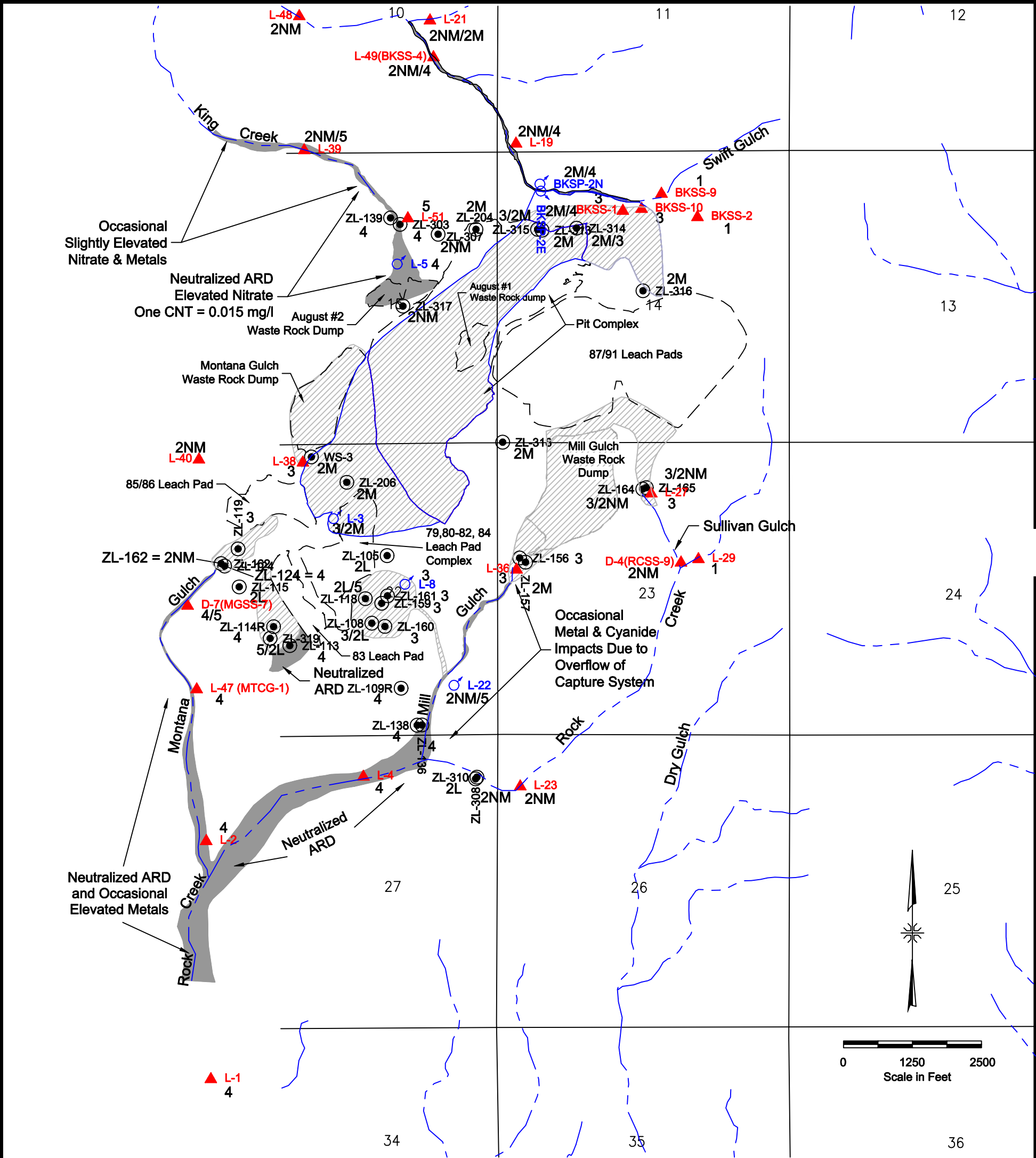
The classification system was not defined with respect to State of Montana water quality standards since interim Consent Decree standards are currently in effect at the mines. Some parameters such as nitrate were indicative of mine impacts at levels below regulatory standards (e.g. below the maximum contaminant level of 10 mg/l for nitrate).

The results of the water quality classification demonstrate that ARD impacts from the mines are limited to areas beneath and immediately downgradient of pits, rock dumps and leach pad dikes. ARD-neutralized zones and low level/occasional mine-related contaminants extend downgradient of these facilities. Treated water from the water treatment plants is ARD-Neutralized type. A discussion of current conditions in each drainage, based on the water classification system, follows in Sections 3.3.6 and 3.3.7.



# ZORTMAN MINE WATER CLASSIFICATION

FIGURE 3.3-16



CLASSIFICATIONS

- 1 - Headwaters Background, GW & SW
- 2M - Mineralized Syenite Background GW & SW
- 2NM - Non-Mineralized Syenite Background GW & SW
- 2L - Limestone Background GW
- 3 - Mine/ARD Impacted, GW & SW
- 4 - Neutralized ARD-Mixed GW & SW
- 5 - Various Mine-related indicators at low levels or occasionally (NO<sub>3</sub>-N, As, Metals, CNT), non-Type 4

LEGEND

- RG-4 Active Monitoring Well
- ▲ Z-59 Stream Flow Monitoring Station
- ♂ L-22 Spring, Seep, or Adit Monitoring Station

# LANDUSKY MINE WATER CLASSIFICATION

FIGURE 3.3-17

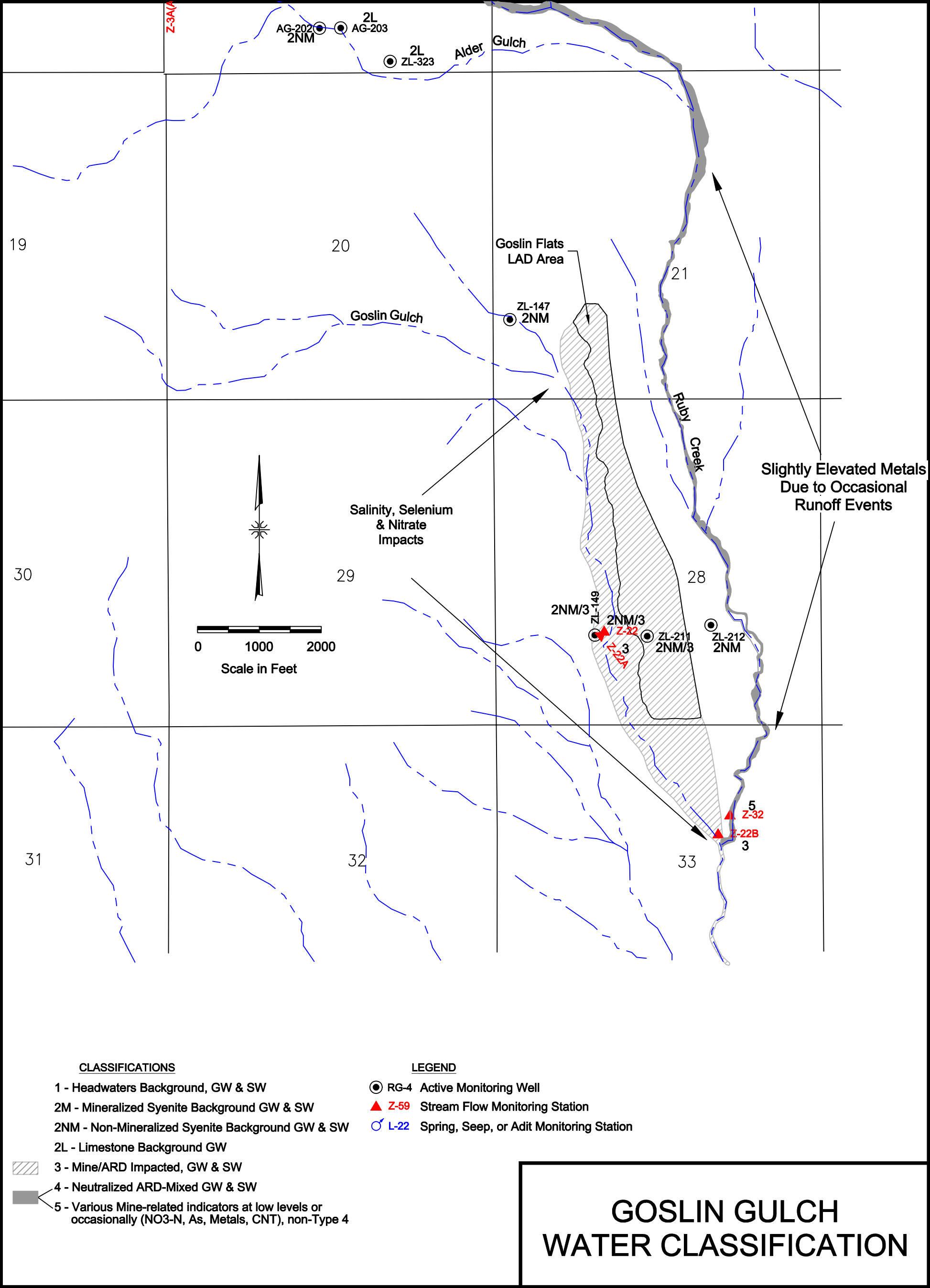


FIGURE 3.3-18

### **3.3.6 Zortman Mine Drainage Basin Hydrology**

#### **Ruby Gulch**

Ruby Gulch is located in the northeastern portion of the Zortman Mine area (Figure 3.3-4). The majority of the mine facilities are within the northwestern portion of the Ruby Gulch drainage and include the Ruby, O.K., Mint and North Alabama pits, the northern portion of the South Alabama pit, a portion of the Z79/80/81, and Z83 leach pads, the Z85/86 and Z89 leach pads and dikes, the O.K. and Ruby Gulch waste rock facilities, the Zortman Mine process plant and water treatment plant, the Ruby Gulch capture system and pond, and the Ruby Gulch tailings deposit. The location of facilities is shown on Figure 3.3-19.

A permanent capture system was constructed in 1994 to replace the interim system. This system captures seepage from the Z85/86 leach pad underdrain (at Z-37), buried seeps and springs, and possibly buried adit discharge, as well as upgradient surface mine drainage runoff. Captured water is pumped to the Zortman Mine water treatment plant.

Ruby Gulch receives discharge from the Zortman Mine water treatment plant, which treats water captured in upper Ruby Gulch, Alder Spur, and Carter Spur. The flow of Ruby Gulch, ranging from 0 to 2 million gallons per day, is almost wholly provided by discharge from the water treatment plant. Due to the low flows in these drainages during much of the year, and the capacity of pre-treatment holding ponds, the water treatment plant only operates intermittently. A dramatic improvement in the quality of the surface water has been observed since initiation of capture and treatment.

#### **Ruby Gulch Tailings**

The Ruby Gulch tailings deposit was generated by historical mining operations predating the open pit operations. The mine tailings deposit overlies the native alluvium of Ruby Gulch. The tailings extend from the Ruby Gulch capture system downstream through the town of Zortman. Between the capture system and the mine gate, the tailings cover approximately 19.4 acres at an average depth of six feet.

The tailings are composed primarily of oxidized syenite porphyry. Acidity testing of the tailing material was performed by Robertson (1999). Field pH values ranged from 5.8 to 7.6 s.u. TDS ranged from 70 to greater than 2,000 mg/l, with a mean of 800 mg/l. The results of geochemical testing using ABA methods indicate that the Ruby tailings are NAG material.

Two monitoring wells, RG-110 and ZL-143, are screened through the Ruby Gulch tailings and underlying alluvium. Water quality data from these wells indicates that the water is primarily classified as neutralized ARD, with occasional elevated metals and nitrate. Water quality in these wells is probably influenced by the discharge from the Zortman water treatment plant. However, it has lower TDS than the treatment plant discharge, indicating the input of other non-mine recharge. On rare occasions, spikes of ARD-impacted water apparently reaches these wells, resulting in temporary elevated sulfate, TDS and metals, and

depressed pH and alkalinity. Due to the apparent association with spring and early summer, mine runoff is the likely source of these short-term events.

### **Monitoring Stations**

*Surface Water:* Eleven upper and lower Ruby Gulch monitoring stations were used to evaluate surface water conditions in the FEIS (p. 3-58). The 11 surface water monitoring stations used for interpretations in the Groundwater Study included four FEIS stations and seven additional sites (WMCI, pp. 397-398). Station locations are shown in Figure 3.3-19b. Many of the surface water stations were temporary gauging sites and have a limited period of record. In accordance with the Consent Decree, only one station located below the water treatment plant (Z-15), is routinely monitored.

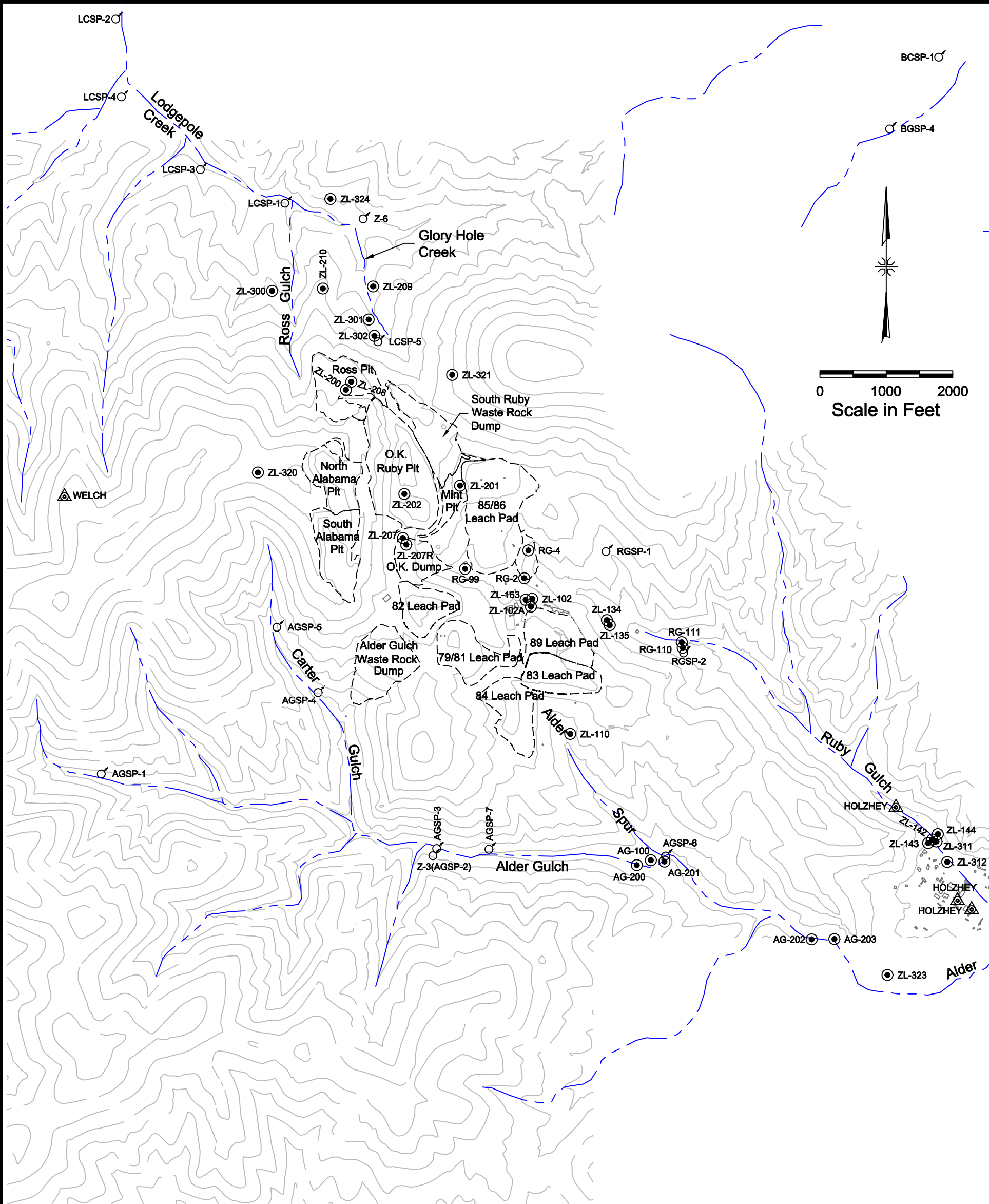
*Groundwater:* One new monitoring well, ZL-312, and one piezometer, ZL-311, were installed in lower Ruby Gulch for the Groundwater Study. ZL-312 is a deep well (screened interval 656-697 feet below ground level (bgl)) completed in the top of the Mission Canyon Formation. A total of 26 wells, including the two new wells, were used in the Groundwater Study evaluation. The FEIS evaluation used 13 of these wells. Well locations are shown on Figure 3.3-19a.

Additional information regarding surface and groundwater monitoring stations can be found in Gallagher (1999) and HSI and Gallagher (2001).

### **Water Quality**

*FEIS Surface Water Conditions:* The 1996 FEIS noted declining surface water quality in the upper Ruby Gulch drainage, mostly due to deepening of the pits into the sulfide (FEIS, p. 3-58). Impacts to downgradient surface water quality in the vicinity of the Zortman townsite were much less severe but included elevated concentrations of sulfate, TDS, SC and metals, and depressed pH conditions. After extreme rainfall or snowmelt, impacts to water quality were seen 1.5 miles downstream from the town of Zortman at Z-32, before the Ruby Gulch capture system was installed (FEIS, p. 3-61).

*FEIS Groundwater Quality Conditions:* The FEIS concluded that groundwater beneath and immediately downgradient of the pits in upper Ruby Gulch has been impacted by mining operations (FEIS, p. 3-98). Groundwater beneath the pits exhibited the poorest quality with low pHs (generally below 4 s.u.), and high SC, sulfate and metals concentrations. Groundwater between the pits and the town of Zortman had variable water quality, but was generally less impacted than beneath the pit area. Water in a shallow Madison Group well (ZL-142) near the Zortman Mine had a neutral pH, but elevated specific conductance (SC) and sulfate, suggesting the water recharging the limestone was impacted by neutralized ARD (FEIS, p. 3-98). Additionally, cyanide was detected a number of times at trace concentrations in water from the adjacent alluvial well, ZL-143. The Zortman townsite water supply well, Z-8A, was not affected by discharges or seepage from the mine.



**ZORTMAN MINE  
MONITORING SITES  
(Groundwater)**

FIGURE 3.3-19a



Current Water Quality Conditions: Figure 3.3-16 shows the area of impacted surface and groundwater in Ruby Gulch based on the classification system described in Section 3.3.5. A summary of post-1995 water quality trends is presented in Table 3.3-2. Trends in pH and sulfate for key downstream stations are provided in Figures 3.3-20 and 3.3-21.

*Current Surface Water Conditions:* Seepage from the Z85/86 pad underdrain, buried springs and/or discharge from the buried mine adits is captured at station Z-37 and pumped to the Zortman Mine water treatment plant. This seepage represents the most concentrated ARD on either mine site, and is classified as Type 3 water quality (SEIS, Section 3.3.5). Since 1995, the captured seepage quality has remained generally stable, with only a slightly increasing sulfate trend.

Since the flow in Ruby Gulch is generally the result of controlled discharge from the Zortman Mine water treatment plant (except during wet periods), water quality in the drainage at station Z-15 typically is classified as neutralized ARD (Type 4). The treated water meets the effluent limits specified by the Consent Decree, as shown by data from outfall samples (#667). The characteristics of the treated water include elevated total dissolved solids, sulfate, hardness, and nitrate.

Ruby Creek below the Zortman Mine flows only in response to major runoff events so it is sampled infrequently. Elevated metals concentrations were evident in two post-1995 runoff events. Otherwise, there is no evidence of mining-related impacts down to the confluence with Goslin Gulch, about three miles south of the town of Zortman.

*Current Groundwater Quality Conditions:* Groundwater (up to 500 feet bgl) beneath the pits is impacted by the pits, exhibiting low pH values and elevated SC and metals concentrations. Post-1995 data indicate that the groundwater pH in the vicinity of the pits is generally stable. However, SC, sulfate and metals are increasing (Table 3.3-2). All groundwater in the vicinity of the pit is classified as Type 3, mine/ARD-impacted quality.

As noted, water discharged from the Zortman Mine water treatment plant represents neutralized ARD quality (Type 4). Alluvial groundwater immediately below the water treatment plant discharge represents a mixed type (Type 3/2NM) with most samples exhibiting ARD-related impacts as shown by data from well RG-110. Deeper syenite bedrock groundwater is not impacted by mining activities and is classified as non-mineralized background quality (Type 2NM) based on data from RG-111, located adjacent to RG-110. Near the mouth of Ruby Gulch, shallow groundwater in alluvium, and in bedrock aquifers in contact with alluvium (ZL-142), reflects treated water quality, i.e. neutralized ARD (Type 4).

Deep groundwater (more than 655 feet bgl) in the Madison Group Mission Canyon Formation (ZL-312) near Zortman mostly resembles natural limestone water quality. However, it contains elevated arsenic concentrations (more than 0.1 mg/l), although values have declined and stabilized since June 1997. Slightly elevated levels of iron and manganese have also been detected, although no other ARD or neutralized ARD indicators were seen. Well logs for ZL-312 indicate this well was screened through pyritized limestone,

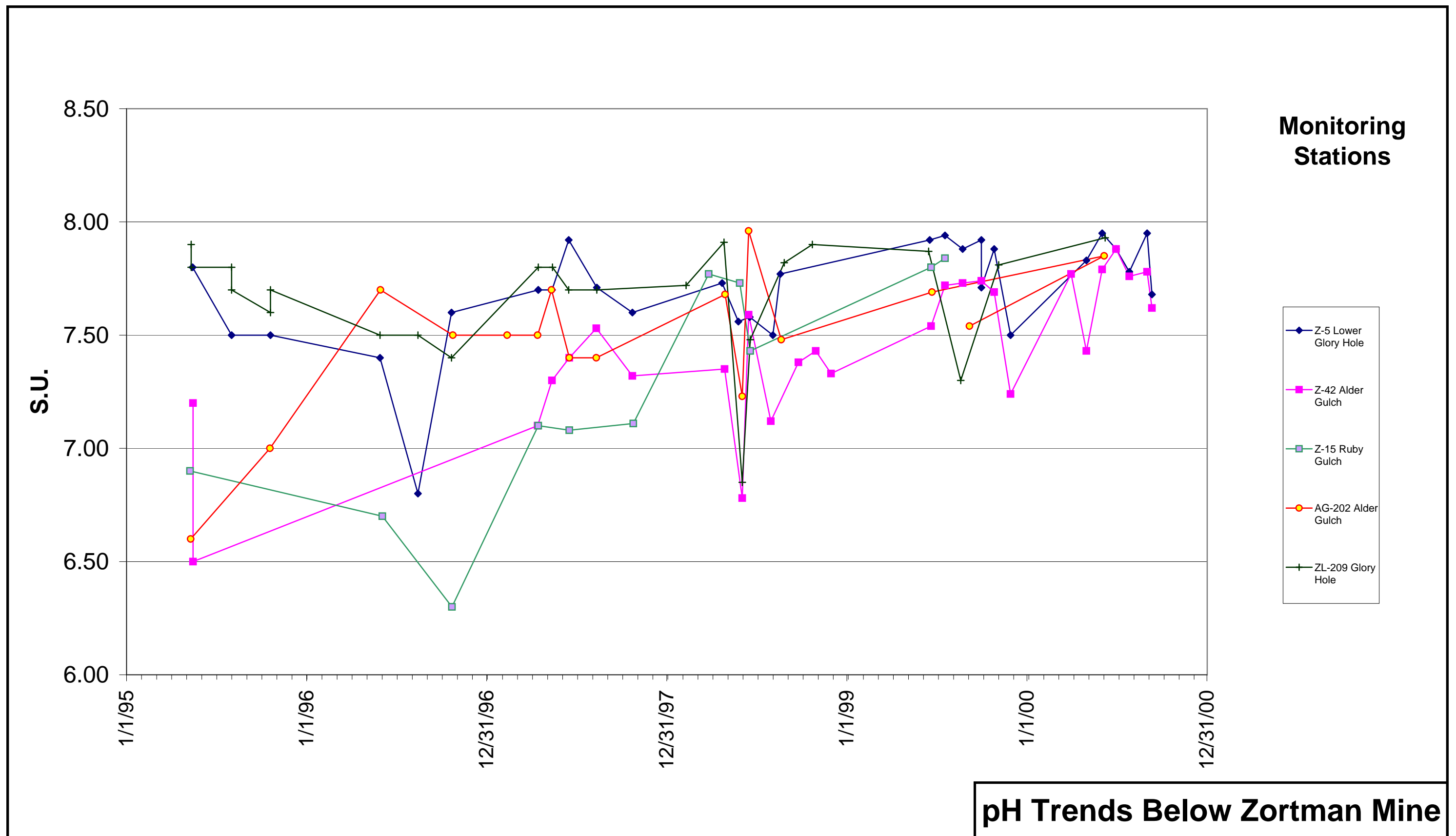


FIGURE 3.3-20



indicating natural mineralization of the limestone in this area. The water quality of this aquifer is classified as natural limestone type background with mining-related impact indicators. However, natural mineralization may be responsible for some or all of the metal detections.

Based on monitoring results at alluvium/bedrock well pairs RG-110/RG-111 and ZL-142/ZL-312, the worst-case locations for potential mining impacts, vertical migration of contaminants into deeper groundwater flow systems in Ruby Gulch may have occurred, but only to a minor extent.

The Zortman Water Balance and Mass Loading report (Spectrum 2000a) defined current loads of metals and sulfate to the subsurface, which included loading to groundwater, and to groundwater that becomes surface water within or near the mine site. Mass loading calculations indicate nearly 70% of the Ruby Gulch metals and sulfate loads are contributed by the mine pits (Spectrum 2000a). However, the majority of seepage to the subsurface is collected and treated. Including the leach pads, the Ruby Gulch drainage contains an estimated 78% of the total sulfate load and 82% of the total metals load produced by the entire Zortman Mine. Of the total mine contaminant load in the groundwater, excluding leach pads, Ruby Gulch contains an estimated 73% of the sulfate load and 76% of the total metals load. These estimates include mine-related and natural background loads. Over the entire Zortman Mine site, the total metals and sulfate loads to groundwater not captured is estimated at 3% and 2%, respectively.

### **Alder Gulch**

The Alder Gulch basin in the southern portion of the Zortman Mine has several tributaries, including Carter Gulch, Carter Spur, Alder Spur and Pony Gulch (Figure 3.3-4). Zortman Mine facilities located in the Alder Gulch drainage basin include the Z83/84 leach pads and dikes, the Alder Gulch waste rock dump, the majority of the Z79/80/81 leach pads, the Z83 leach pad, a portion of the Z82 pad, the west half of the North Alabama pit, and the South Alabama pit. The locations of facilities are shown in Figure 3.3-4.

In late 1996, permanent capture systems began operating below the Z83/84 dikes in Alder Spur, and below the Alder Gulch waste rock dump in Carter Spur. The Alder Spur capture system was designed to capture water penetrating the Z83 and Z84 dikes that surfaced at the toe of the facility. The Carter Gulch seepage capture system was designed to capture water penetrating the Alder Gulch waste rock dump that surfaced at the toe of the dump. Captured seepage is pumped to the Zortman Mine water treatment plant. The treated water is then released into Ruby Gulch.

Improvements in water quality were evident in downgradient surface and groundwater after installation of the capture systems. Seepage from the Alder Gulch waste rock dump and the Z83/84 leach pad underdrains was the major contributor to poor water quality downgradient from these facilities. Seepage from the waste rock dump continues to be of poor quality, while that from the leach pad underdrains has improved somewhat. Mining impacts are not present in surface and groundwater near the mouth of Alder Gulch.

## Monitoring Stations

*Surface Water:* Seven monitoring stations were used to evaluate surface water conditions in the FEIS (p. 3-61), while 54 stations were reviewed for the Groundwater Study, including 30 new sites (WMCI, p. 360). Many of these sites were temporary stream gauging stations used for the synoptic stream surveys to evaluate losses to or gains from groundwater along the stream channel. All stations used for the FEIS were also used in the Groundwater Study. Surface water station locations are shown in Figure 3.3-19b. Many stations have a limited period of record.

*Groundwater:* One new well, ZL-323, and one piezometer, ZL-320, were installed in Alder Gulch for the Groundwater Study. A total of 10 monitoring points, including the new well and piezometer, were used in the Groundwater Study. The FEIS used six of these wells. Locations are shown in Figure 3.3-19a. Additional information on surface and groundwater monitoring stations can be found in Gallagher (1999) and HSI and Gallagher (2001).

## Water Quality

*FEIS Surface Water Quality Conditions:* The 1996 FEIS noted impacts in Alder Gulch due to seepage from the waste rock dump. Impacts include decreasing pH and elevated sulfate, TDS and SC concentrations (FEIS, pp. 3-68 and 3-70). Surface water quality was also affected by spills and land application of process chemicals, with cyanide detections below the Alder Spur confluence. The FEIS noted that the capture and pumpback systems at that time were improving water quality in Alder Gulch below Alder Spur (Z-8).

*FEIS Groundwater Quality Conditions:* The FEIS concluded that alluvial groundwater near the mouth of Alder Spur had been impacted by the land application disposal used in 1986/87 (FEIS, p. 3-98). Deeper groundwater (160-200 feet bgl) under the Alder Gulch waste rock dump (located in Carter Spur) was not impacted by seepage from the dump, as indicated by decreasing levels of SC, TDS and hardness at ZL-107R. Deeper bedrock groundwater in Alder Spur did not show impacts due to mining (ZL-110). Most alluvial water showed a period of degraded water quality during 1991 with improvements since that time to 1995 (FEIS, p. 3-98).

*Current Water Quality Conditions:* Figure 3.3-16 shows the area of impacted surface water and groundwater in Alder Gulch based on the classification system described in Section 3.3.5. A summary of current water quality conditions and post-1995 water quality trends is presented in Table 3.3-2. Trends in pH and sulfate for key downstream stations are provided in Figures 3.3-20 and 3.3-21.

*Current Surface Water Quality Conditions:* Water quality at the Carter Spur pumpback, station Z-13, shows a continuing decline in pH to near 3 s.u., and widely fluctuating, but continuing increases in sulfate, specific conductance and metals concentrations. In contrast, since 1995 at the Alder Spur pumpback station (Z-14), pH has increased to around 6 s.u., metals concentrations have declined, and sulfate and specific

conductance have leveled off. While these waters are both consistent with the Type 3 (mine/ARD impacted) classification, ARD from the waste rock dump is more concentrated than ARD from the underdrains. Surface water in the mainstem of Alder Gulch, downgradient from the Carter Gulch and Alder Spur confluence (Z-8), is typical of unimpacted non-mineralized water quality (Type 2). Post-1995 data from this area shows that with the exception of occasional elevated iron concentrations, surface water is of good quality with pH values between 7 and 8 s.u., low SC, low metal levels, and no nitrate detections.

*Current Groundwater Water Quality Conditions:* Water quality in Alder Gulch has improved since construction of the capture systems. 1997-2000 data indicate that alluvial groundwater near the mouth of Alder Gulch (AG-201, AG-202) does not exhibit impacts from mine activities, nor does groundwater in the deeper limestone aquifer. With the exception of one slightly elevated nitrate value (1.5 mg/l), deeper groundwater in Alder Spur is representative of non-mineralized syenite background water quality.

Based on monitoring results, the underlying syenite groundwater is not impacted by vertical migration of contaminants from surface water. There is no evidence of vertical migration of mine-impacted alluvial water to the limestone aquifer as shown by data from monitoring well ZL-323.

The Zortman Water Balance and Mass Loading report (Spectrum 2000a) defined current loads of metals and sulfate to the subsurface, which included loading to groundwater, and to groundwater that becomes surface water within or near the mine. Mass loading calculations indicate over 44% of the sulfate load and 68% of the metals load in Alder Gulch are contributed by the Alder Gulch waste rock dump (Spectrum 2000a). However, the majority of seepage to the subsurface is collected and treated. Including leach pads, Carter Gulch contains approximately 13% and 17%, respectively, of the total Zortman Mine sulfate and total metals loads to groundwater. Excluding leach pads, Carter Gulch contains an estimated 25% of the sulfate load and 23% of the total metals load, representing the portions of the mine loads that reach groundwater. Alder Spur contains about 8% of the sulfate load and 1% of the total metals load produced by the Zortman Mine. Of the total mine contaminant load in the groundwater, excluding leach pads, Alder Spur contains an estimated 2% of the sulfate load and 0.2% of the metals load.

## **Goslin Gulch**

Goslin Gulch is located approximately one mile south of the town of Zortman, and joins Ruby Creek approximately three miles south of the town of Zortman. Goslin Gulch is an ephemeral drainage with several low-yielding springs. Discharge from the springs and ponds produces short reaches of surface flow and/or standing water; however, the channel is typically dry. There are at least three stock ponds in the creek that are fed by springs and runoff water.

Alluvial terraces flanking Goslin Gulch were identified in 1991 as potential LAD areas for leach pad waters. The baseline groundwater conditions in the Goslin Flats LAD area were investigated and reported by Hydrometrics (1991) and WMCI (1998). Groundwater occurs in the alluvium of Ruby Creek and Goslin Gulch, and in the underlying Thermopolis shale bedrock.

A 55-acre LAD area was developed within the Goslin Gulch basin by ZMI, beginning in June 1998. It was expanded to 96 acres in 1999, and to 410 acres during 2000, and then reduced in 2001 to 364-acres due to soils limitations. Leach pad solutions from the mines have been applied through sprinklers to the LAD for treatment of metals and nitrate. A total of 107, 108 and 137 million gallons of leach pad solutions were applied to the LAD area in 1998, 1999, and 2000, respectively. The location of the LAD area is shown in Figure 3.3-22.

The initial LAD area was not originally designed as a zero discharge system, and seepage of groundwater from the LAD area to Goslin Gulch occurred from 1998 to 2000. The discharge of spring Z-22 on the southwest edge of the original LAD area increased, and the concentration of salts, nitrate and trace elements also increased. New springs and seeps appeared on the west side of the LAD, near Goslin Gulch. Selenium, which is present in the L87 and L91 leach pads at concentrations up to 1.2 mg/l, was detected in samples of springs in Goslin Gulch.

The expansion of the LAD to 364 acres led to a decline in the amount of discharge and contaminants reaching Goslin Gulch, surface water and groundwater. The water management plan for the Goslin Flats LAD is in the Goslin Flats Land Application Disposal Expansion Assessment and 2000-2001 Plan of Operations (HSI/Spectrum 2000). Continued monitoring of surface water, groundwater, soils and vegetation in the LAD area is part of the present operating plan.

### **Monitoring Stations**

*Surface Water:* A total of 12 surface water monitoring stations (including springs) have been established in the Goslin Flats LAD area. Some of these only flow seasonally or in response to large storm events. Monitoring station locations are shown on Figure 3.3-22.

*Groundwater:* A total of 16 monitoring wells have been installed in the Goslin Flats area. Well locations are shown on Figure 3.3-22. Detailed information regarding surface water and groundwater stations can be found in HSI/Spectrum (2000), and in HSI and Gallagher (2001).

### **Water Quality**

*FEIS Surface Water Quality Conditions:* The 1996 FEIS noted that surface waters in Goslin Gulch were near neutral in pH, but had elevated sulfate, SC and TDS. This was attributed to water interacting with the marine shale bedrock beneath the area (FEIS, p. 3-67).

*FEIS Groundwater Quality Conditions:* The FEIS concluded there were no mining-related impacts to Goslin Flats groundwater. Elevated TDS and sulfate concentrations in the alluvial and shallow bedrock aquifers in Goslin Flats are the natural result of the interaction of water with the underlying mineral-rich shales (FEIS, p. 3-98).

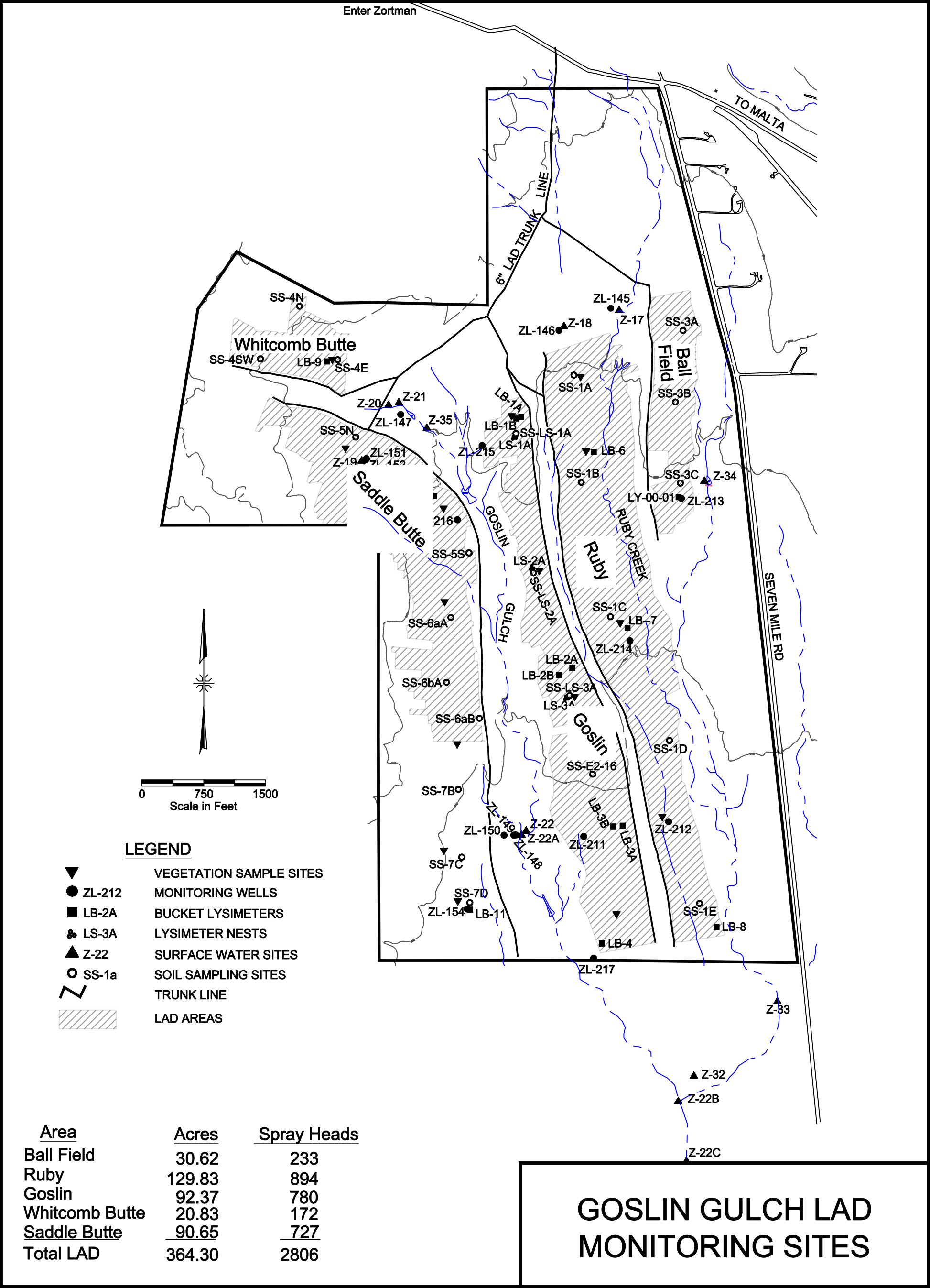


FIGURE 3.3-22

Current Water Quality Conditions: Figure 3.3-18 shows the area of impacted surface and groundwater in Goslin Gulch based on the classification system described in Section 3.3.5. A summary of post-1995 water quality trends is presented in Table 3.3-2.

*Current Surface Water Quality Conditions:* Baseline studies in Goslin Gulch show that many parameters were naturally above drinking water standards (WMCI, p. 487). WMCI reported naturally occurring elevated levels of aluminum, arsenic, iron, lead, manganese and selenium in springs within the basin. Ruby Creek below the confluence with Goslin Gulch has been impacted by mining-related contaminants since the Goslin Flats LAD was placed in operation in 1998. These contaminants have included nitrate, selenium, cyanide and salinity. The expansion of the LAD area has significantly reduced the total discharge from the LAD reporting to Goslin Gulch. On July 7, 2000, Goslin Gulch flowed about 20 gpm at station Z-22A within the LAD area, and 46 gpm at Z-22B, in Goslin Gulch just above the confluence with Ruby Creek. The first of the expansion areas was initiated in mid-July 2000. Flow gradually declined after that, to approximately 6 gpm at Z-22A, and zero flow at Z-22B by December 26, 2000. No flow was measured at Z-22B throughout the winter. Neither station had any flow from early April through June 2001. Station Z-22B remained dry until mid-August when 13 gpm was recorded. Flow increased to a maximum of 31 gpm on August 30, following which it declined through September 2001 to 9.5 gpm. A combination of site conditions and operational factors apparently caused the re-start of flow in Goslin Gulch in August 2001. Water application to the LAD was modified when flow was observed. Water quality sampling of Goslin Gulch at Z-22B on August 30, 2001, showed elevated total dissolved solids (4,966 mg/l), nitrate (187 mg/l) and selenium (0.436 mg/l), and slightly elevated cyanide (0.235 mg/l total). The impacts to lower Ruby Creek are generally limited to the zone from Goslin Gulch to the county “cut-across road,” located approximately two miles below Goslin Gulch, where Ruby Creek is typically dry.

*Current Groundwater Quality Conditions:* Discharge from the LAD has impacted shallow alluvial groundwater in Goslin Flats with increases in nitrate, selenium, cyanide and salinity. Deeper groundwater in the Thermopolis shale is of naturally poor quality, with TDS in the range of 1,700-1,900 mg/l due to soluble salts within the formation. Groundwater in the bedrock aquifer has generally not been impacted by LAD operations. One bedrock well (ZL-148 in the Thermopolis shale) showed LAD-related impacts, with nitrate concentrations at 11.5 mg/l and small amounts of selenium and cyanide in a sample from August 2000. Water quality trends in Goslin Gulch are summarized in Table 3.3-2.

In order to reduce the potential for contaminants to reach surface and ground water in Goslin Gulch, a biological treatment plant is to become operational in the spring of 2002. The plant is designed to remove nitrate, selenium, and cyanide from the LAD waters prior to application. Consequently, future land applied waters would likely contain only relatively small concentrations of these substances.

## **Lodgepole Creek**

Lodgepole Creek, and headwater tributaries Glory Hole Creek and Ross Gulch, drain the northern end of the Zortman Mine (Figure 3.3-19). The Ross pit is located in this area of the basin. At least two historic

adits, including the Pink Eye Pearl adit, daylight in upper Ross Gulch. The location of the mine facilities is shown in Figure 3.3-4. The surface water and groundwater in the mainstem of Lodgepole Creek are not impacted by mining activities.

### **Monitoring Stations**

*Surface Water:* Surface water quality in Lodgepole Creek was evaluated in the FEIS using results from five monitoring stations (FEIS p. 3-67). The Groundwater Study utilized 29 stations to evaluate surface water conditions, including the FEIS stations and 22 new stations (WMCI, pp. 437-439). Station locations are shown in Figure 3.3-19b. Many of these were temporary stream gauging stations and have a limited period of record. In accordance with the Consent Decree, Z5, located at the mouth of Glory Hole Creek, and S-1 (LCSS-4), located in Ross Gulch, are the only stations routinely monitored.

*Groundwater:* A total of five new wells and piezometers were drilled in the Lodgepole Creek drainage for the Groundwater Study. These include ZL-300, located in the Ross Gulch area; ZL-301 and ZL-302, completed in syenite porphyry in Glory Hole Gulch; ZL-321, a Precambrian gneiss well located upgradient of Glory Hole Creek on Shell Butte; and ZL-324, also a Precambrian gneiss well located north of Lodgepole Creek. A total of 7 monitoring points, including the new well and piezometer, were used in the Groundwater Study. The FEIS used two of these wells. Locations are shown in Figure 3.3-19. Additional information regarding surface and groundwater stations can be found in Gallagher (1999) and HSI and Gallagher (2001).

### **Water Quality**

*FEIS Surface Water Quality Conditions:* The 1996 FEIS reported that surface water quality impacts in Lodgepole Creek have been minimal and are restricted to Glory Hole Creek at Station Z-5. Neutral pH values, low TDS and sulfate, and no cyanide detections indicate that impacts to Lodgepole Creek have only been short-term (FEIS, Table 3.2-32).

*FEIS Groundwater Quality Conditions:* The FEIS concluded there were few, if any, impacts to groundwater in Lodgepole Creek from mining activities (FEIS, 3-98). This conclusion was based on analytical data from wells ZL-209 and ZL-210, and spring Z-6.

*Current Water Quality Conditions:* Figure 3.3-16 shows the area of impacted surface water and groundwater in Lodgepole Creek based on the classification system described in Section 3.3.5. A summary of current conditions and post-1995 water quality trends are presented in Table 3.3-2. Trends in pH and sulfate for key downstream stations are provided in Figures 3.3-20 and 3.3-21.

*Current Surface Water Quality Conditions:* Surface water in the mainstem of Lodgepole Creek does not show impacts from mining activities, with surface waters classifying as non-mineralized syenite background (Type 2NM). Minor and transient impacts have been detected in both Ross Gulch and Glory

Hole Creek as shown by water quality at stations LCSS-3 and Z-5, respectively. The upper portions of these drainages are classified as mixes of headwaters water quality (Type 1) with events of non-ARD related mine impacts (Type 5), primarily due to nitrate (1 to 2 mg/l), and slightly elevated metals. No mining impacts are present in Lodgepole Creek below the confluence with Ross Gulch or Glory Hole Creek.

*Current Groundwater Quality Conditions:* Mining activities have impacted groundwater beneath the Ross pit. This is confirmed by data from monitoring wells ZL-200 and ZL-208, and exploration hole 97ZH-018. Data show decreased pH, elevated SC, sulfate, and metals typical of Type 3 (mine/ARD impacted) water quality at these locations. Shallow groundwater impacts extend north approximately 500 feet downgradient from the Ross pit in upper Glory Hole Gulch where mine-affected water discharges at spring LCSP-5. However, deeper groundwater in this area represents naturally mineralized syenite water quality (Type 2M) as evidenced by data from ZL-302. Deeper groundwater in Ross Gulch (ZL-300) does not show any mining impacts and currently represents non-mineralized syenite background (Type 2NM) water quality.

The Zortman Water Balance and Mass Loading report (Spectrum 2000a) defined current loads of metals and sulfate to the subsurface, which included loading to groundwater, and to groundwater that becomes surface water within or near the mine site. The mass of sulfate and metals loads reaching Lodgepole Creek from the mine cannot be quantified to the same degree as drainages with capture systems. An approximation was made that relied on the water balance (Spectrum 2000a) estimate of 1.653 million gallons of annual groundwater discharge from the mine area to Lodgepole Creek, and the infiltration and chemical loads calculated for the Ross pit. The annual groundwater discharge to Lodgepole Creek represents about 26% of the total annual recharge to the Ross pit (7.9 million gallons). Using this ratio, the annual sulfate load to Lodgepole Creek is approximately 1%, and the total metals load 2% of the total loads produced by the Zortman Mine. Removing leach pads from the estimate, the percentages of mine-area sulfate and metals loads reaching groundwater are 1.9% and 2.3%, respectively. These estimates include contributions by natural mineralization and mining.

## **Beaver Creek**

The headwaters of Beaver Creek are located northeast of the Zortman Mine area (Figure 3.3-4). No mine facilities exist within this drainage. Surface water and spring data for Beaver Creek show the drainage is not impacted by mining activities, and the water quality is representative of baseline conditions.

**Table 3.3-2. Current Water Quality Conditions and Trends in Zortman Mine Drainage Basins**

Drainage	Area Summary	Station Type	Current Water Class.	Trends				Remarks
				pH	Alkalinity	Sulfate/SC	Metals	
Ruby Gulch	Mine Area/ Pits	Source	3	stable, low	stable, 0	sl + to +	stable to +	ARD is strong and may be approaching maturity.
	Lower Ruby Creek	Down-gradient	4/3/5	stable	stable	stable, + Lower Ruby	stable, low	Ruby Creek has episodic impacts, little effect on beneficial uses.
Alder Gulch	Alder Spur	Source	3	variable	variable	sl +	variable	Seasonal fluctuation/event driven changes in water quality evident.
	Carter Spur	Source	3	stable to sl -	stable, 0	+	+	
	Lower Alder Gulch	Down-gradient	2NM/2L	stable	stable	stable	stable	
Goslin Gulch	Goslin LAD Summary	Source	3	stable, low	stable, high	+	metals low, selenium elevated	Occasional impacts from nitrate, selenium, cyanide and salinity.
	Goslin Gulch below LAD Summary	Down-gradient	3	stable	stable, high	-2	metals low, selenium elevated, declining in 2000	Impacts from nitrate, selenium, cyanide and salinity, but decreasing trend in 2000.
Lodge-pole Creek	Upper Glory Hole	Source	1/3 - shallow 2NM-deeper	stable	stable	stable	stable, low	Spring LCSP-5 (Z-302).
	Upper Ross	Source	1/5, 2NM, 2NM/5	variable	stable	stable, var.	stable, low	Some elevated metals at LCSP-5 (zinc, iron, manganese; nitrates greater than 1.
	Lodgepole below Ross & Glory Hole	Down-gradient	2NM	stable, sl -	stable to sl -	stable to -	stable, low	Most metals are less than detection level at Z-64. Increases in metals appear to be event driven.
Beaver Creek	Headwaters	Down-gradient	1/2L	stable	sl -	stable, v. low sulfate	iron variable, other metals non-detectable	Mixture of headwaters and limestone background, iron up to 1.2 mg/l, but other metals non-detectable; non-detectable nitrate.

Current Conditions: 1=Headwaters Background; 2M=Mineralized Syenite Background; 2NM=Non-Mineralized Syenite Background; 2L=Limestone Background; 3=Mine/ARD Impacted; 4=Neutralized ARD; 5=Various Mine-Related Indicators. Trends: + increasing; - decreasing; sl=slight

### 3.3.7 Landusky Mine Drainage Basin Hydrology

#### Rock Creek/Sullivan Gulch

The Rock Creek drainage, including Sullivan Gulch, is located on the southeastern side of the Landusky Mine area (Figure 3.3-5). This drainage includes the L91 leach pad and pad dike (located in the uppermost reach of Sullivan Gulch) and the Sullivan capture system. The location of these facilities is shown in Figure 3.3-5.

The Sullivan capture system became operational in 1997 and is designed to capture subsurface flows penetrating the L91 dike and surfacing at the toe of the facility. Captured water is routed to the Landusky Mine water treatment plant. More information on the capture systems can be found in HSI and Gallagher (2001).

Surface water and groundwater data show that contaminants are not migrating beyond the capture system. However, contaminants have reached the bedrock aquifer below the capture system, as shown by data from well ZL-165.

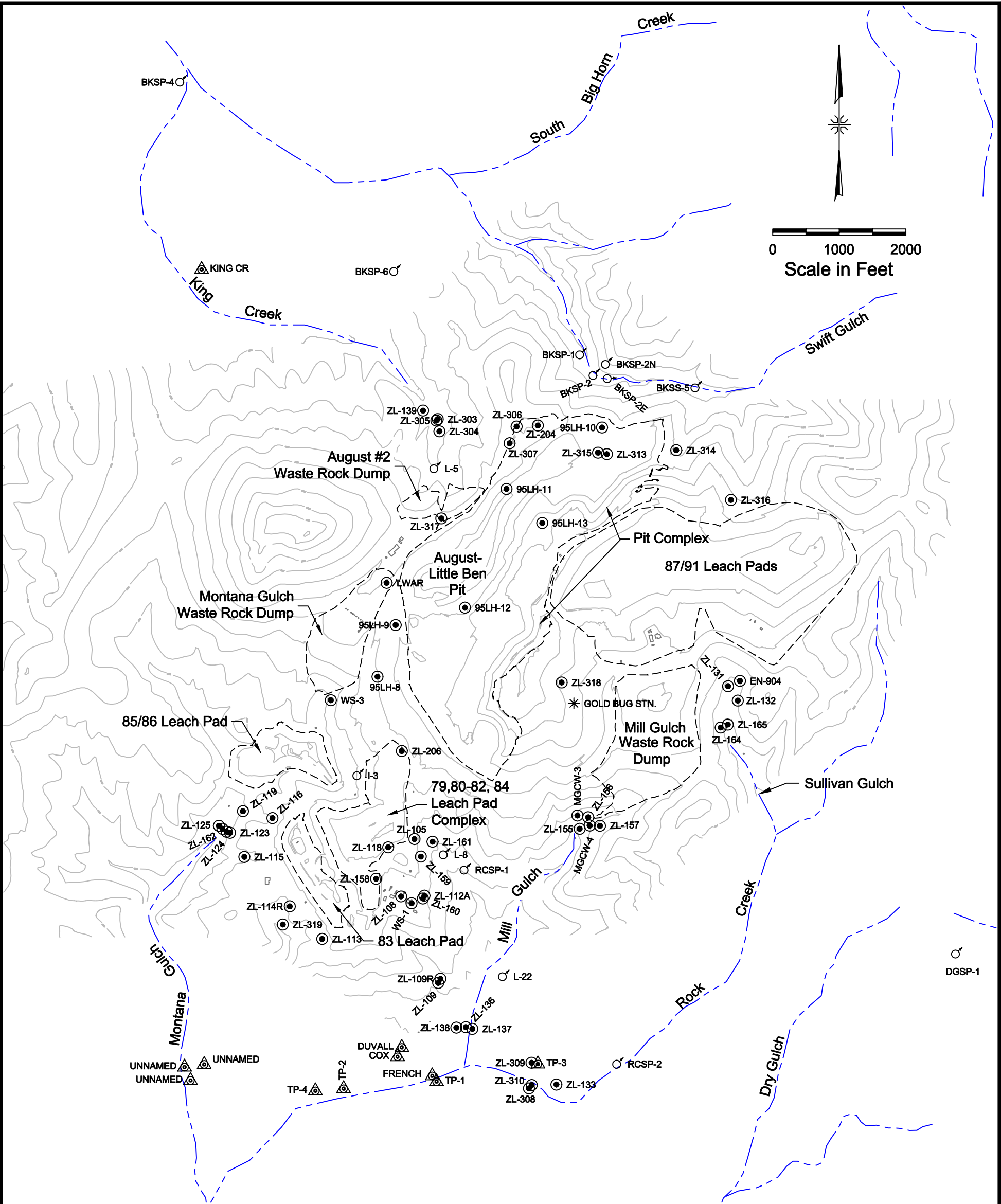
#### Monitoring Station

*Surface Water:* A total of seven upper and lower Rock Creek stations were used in the FEIS to evaluate water quality conditions (p. 3-73). The 22 surface water stations used for interpretations in the Groundwater Study included the seven FEIS stations and 15 additional sites (WMCI, pp. 258-260). Surface water stations are shown in Figure 3.3-23b. Many of the surface water stations were temporary gauging sites and have a limited period of record. In accordance with the Consent Decree only one station, D-4 (located in Sullivan Gulch) is routinely monitored.

*Groundwater:* Two new wells, ZL-308 and ZL-310, and one piezometer, ZL-309, were installed in Rock Creek above the town of Landusky for the Groundwater Study. ZL-308 is completed in alluvium, while ZL-309 and ZL-310 are deeper completions in the Madison Group limestones. A total of 13 wells, including the three new installations, were used in the Groundwater Study (WMCI, p. 259). The FEIS evaluation focused on six of these wells. Well locations are shown on Figure 3.3-23a.

#### Water Quality

*FEIS Surface Water Quality Conditions:* Surface water quality downstream of the L91 leach pad was intensely affected by ARD, as evidenced by low pH and elevated concentrations of sulfate, TDS and SC at station L-28 (FEIS, p. 3-73). Impacts to surface water quality were evident up to 2.5 miles downgradient from the pad at station L-1. However, by 1995 downstream surface water near Landusky (L-4) and downgradient from the Montana Gulch/Rock Creek confluence (L-1) showed no or slight impacts from mining activities (FEIS, p. 3-73).



0 1000 2000  
Scale in Feet

LEGEND

- RG-4 Active Monitoring Well
- L-22 Spring, Seep, or Adit Monitoring Station
- △ BLM Water Supply Well

LANDUSKY MINE  
MONITORING SITES  
(Groundwater)

FIGURE 3.3-23a



*FEIS Groundwater Quality Conditions:* The FEIS concluded that alluvial and bedrock groundwater in upper Sullivan Creek were impacted by ARD from the L91 leach pad dike or underlying acid generating bedrock. This was determined by decreased pH and increased SC, sulfate and metals concentrations in samples from alluvial well ZL-132 and bedrock well ZL-131. No impacts were identified in Rock Creek in and near the town of Landusky, although it was noted that the groundwater quality data was questionable (FEIS, p. 3-99).

*Current Water Quality Conditions:* Figure 3.3-17 shows the area of impacted surface water and groundwater in Sullivan Gulch and Rock Creek, based on the classification system described in Section 3.3.5. A summary of current conditions and post-1995 water quality trends is presented in Table 3.3-3. Trends in pH and sulfate for key downstream stations are provided in Figures 3.3-24 and 3.3-25.

*Current Surface Water Quality Conditions:* The Sullivan Gulch capture system (L-27) collects ARD-impacted waters characterized by low pH, and high TDS, sulfate, metals, and nitrate. Water quality trends indicate gradually worsening ARD characteristics in 1997 and 1998, with conditions improving somewhat to present. At the confluence with Rock Creek, Sullivan Gulch water quality is typical of unmineralized syenite (Type 2NM), as evidenced by data from D-4. There may be a slightly increasing trend in sulfate and TDS, but metals are stable, and pH and alkalinity appear to be slightly increasing. Below Mill Gulch (L-4), surface water is characteristic of neutralized ARD. The pH and alkalinity have remained stable since 1995; however, surface water in this area is not routinely sampled and there is little post-1995 data for sulfate and metals. Below Montana Gulch (L-1) Rock Creek water quality represents neutralized ARD (Type 4) and exhibits upward trends in sulfate, TDS, and selected metals such as copper and zinc.

*Current Groundwater Quality Conditions:* Upstream of the Sullivan Gulch capture system, the alluvial aquifer and bedrock aquifer are ARD-impacted (Type 3), with pH of 4 to 6 s.u., high sulfate and TDS, and elevated metals. The capture system intercepts the entire thickness of alluvial aquifer, sending this groundwater to the Landusky treatment plant. Bedrock groundwater does not show mining-related impacts at existing downstream monitoring stations. Groundwater quality above the confluence with Mill Gulch is characteristic of natural groundwater for the alluvial and bedrock aquifers (Type 2L) as evidenced by data from ZL-308, ZL-310, and ZL-133. The Groundwater Study (WMCI, p. 199) identified a vertically upward gradient in the Madison Group limestones above the Landusky townsite. Therefore, impacts to groundwater in this aquifer are not likely.

Based on the water balance results and average concentrations of parameters, average annual sulfate and total metals loads were evaluated for each facility at the Landusky Mine (Spectrum 2000b). Sullivan Gulch contains approximately 4.3% of the total sulfate load, and 15.7% of the total metals load produced by the Landusky Mine, inclusive of leach pads and background loads. Excluding leach pads, Sullivan Gulch contains 12.9% of the total sulfate load, and 19.2% of the total metals load in the groundwater at the Landusky Mine.

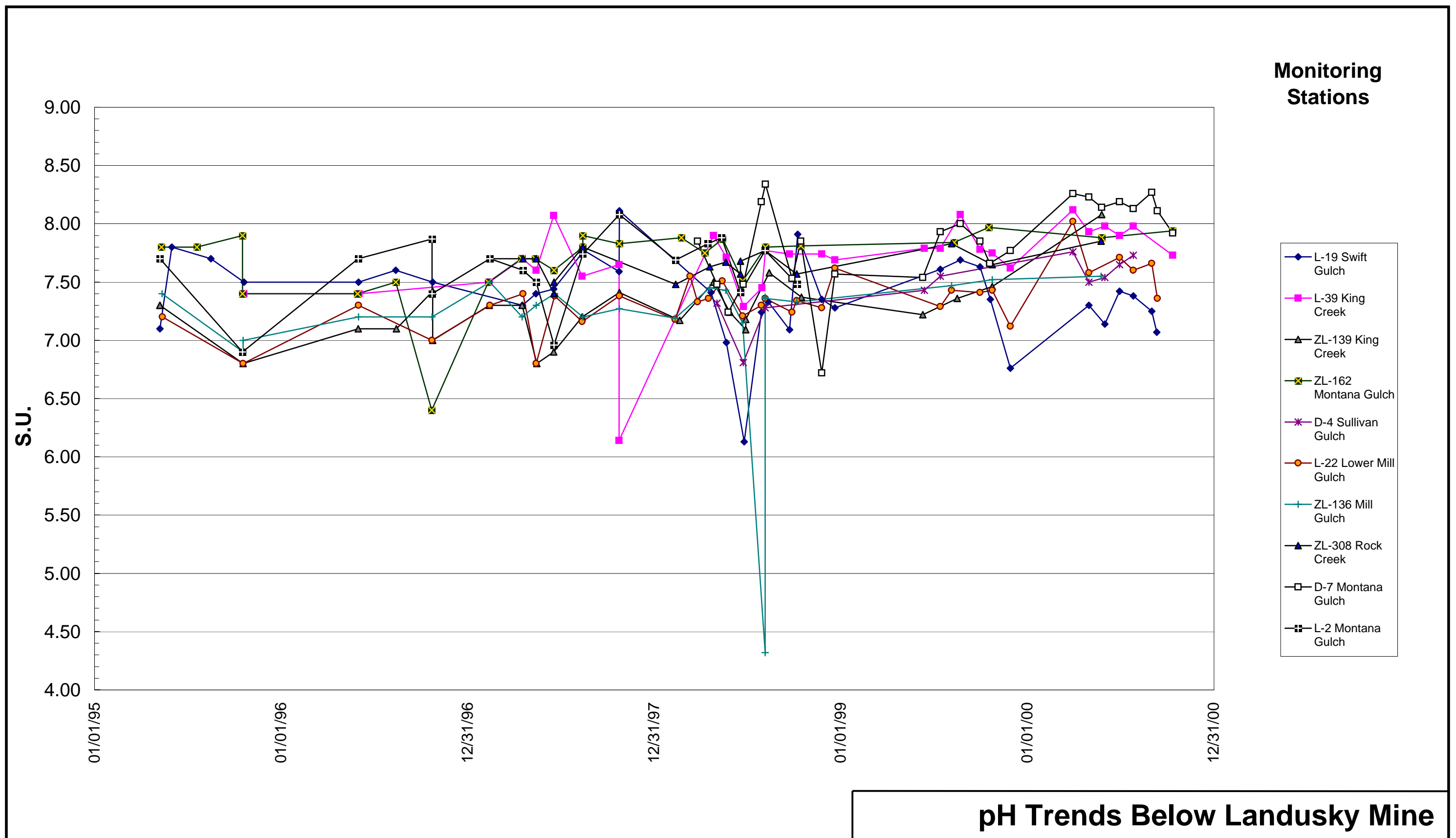


FIGURE 3.3-24

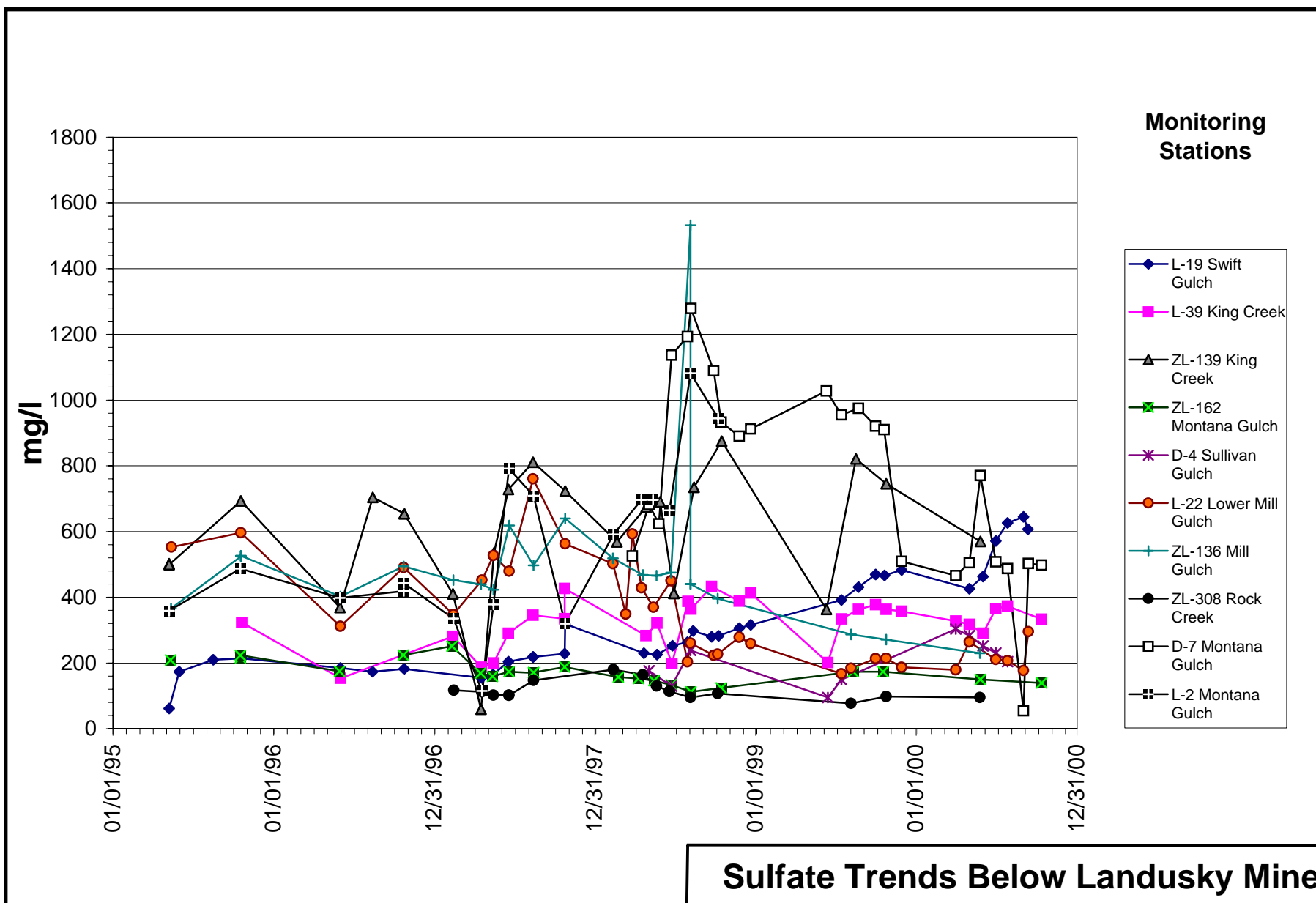


FIGURE 3.3-25

## Mill Gulch

The Mill Gulch drainage is located on the southern side of the Landusky Mine, directly northeast of the town of Landusky (Figure 3.3-5). Mine facilities located in the Mill Gulch drainage include portions of the L79-82, L84 and the L87 leach pads, portions of the Gold Bug pit backfill, the reclaimed Mill Gulch waste rock repository, and the Landusky Mine processing plant. Facilities are shown on Figure 3.3-5. The permanent Mill Gulch capture system became operational in 1997 and was designed to capture subsurface flows penetrating the Mill Gulch waste rock repository and reporting to the toe of the facility. Additional information regarding capture systems is included in HSI and Gallagher (2001).

Areas of surface and groundwater impacted by ARD, nitrate and cyanide exist in Mill Gulch due to acidification of the Mill Gulch waste rock dump, several overflow events in the past four years of the capture system, and spills in the process pond/plant area. A narrow band along the mainstem of the drainage shows a mix of non-mineralized background waters with a lesser amount of impacted surface and groundwater. Below the sedimentary rock outcrops, surface and groundwater in Mill Gulch is neutralized ARD water quality (Type 4).

### Monitoring Stations

*Surface Water:* Nine surface water stations in Mill Gulch were used in the FEIS (p. 3-73) to evaluate water quality conditions, while 17 stations were reviewed for the Groundwater Study, including five new sites. Surface water stations are shown on Figure 3.3-23b. Many of the surface water stations were temporary gauging sites and have a limited period of record.

*Groundwater:* One new monitoring well, ZL-318, was completed in syenite porphyry on the flanks of Gold Bug Butte. A total of 26 wells, including the new well, were used in the Groundwater Study evaluation (WMCI, p. 219). The FEIS evaluation used 20 of these wells (p. 3-99). Well locations are shown on Figure 3.3-23a. Additional information on surface and groundwater monitoring stations can be found in Gallagher (1999) and HSI and Gallagher (2001).

### Water Quality

*FEIS Surface Water Quality Conditions:* The FEIS identified impacts to surface water quality from mining activities throughout the length of Mill Gulch (FEIS, p. 3-77). These impacts were due primarily to the L87 leach pad underdrain, the Mill Gulch waste rock dump, and the Landusky Mine processing plant.

Construction of the L87 leach pad had an immediate impact on the surface water quality of Mill Gulch, with significant decreases in downgradient pH and increases in sulfate, TDS, and SC concentrations (FEIS, p. 3-73). Seepage from the Mill Gulch waste rock dump contributed ARD to downgradient surface water as evidenced by low pH and elevated sulfate, TDS, and SC values at station L-25. In 1995, about 40 gpm of

water draining from the waste rock dump was captured and recirculated onto the L87 leach pad. Several spill events and a process pond leak in the Landusky Mine process plant area were responsible for cyanide detections in surface water downgradient from the plant at L-8 (FEIS, p. 3-77). The ARD-impacted surface waters originating in the headwaters of the drainage were being effectively neutralized by the time they flowed to the lower reaches of Mill Gulch.

*FEIS Groundwater Quality Conditions:* Impacts to alluvial, shallow and deeper bedrock aquifers also resulted from the L87 pad underdrain, the Mill Gulch waste rock dump, and the Landusky Mine processing plant. The alluvial aquifer experienced increases in sulfate, SC and TDS concentrations and declining pH values throughout the length of the drainage. Wells in lower Mill Gulch indicate there is an upward vertical gradient in groundwater flow. Water quality in the alluvial aquifer in this area reflects neutralized ARD (FEIS, p. 3-102).

Cyanide was commonly detected in the shallow and deeper bedrock aquifers downgradient from the processing plant due to spills and liner leaks at this facility. ARD impacts were noted in shallow and deeper bedrock aquifers throughout Mill Gulch. However, the limestone and calcareous formations in lower Mill Gulch appear to neutralize the ARD impacts, as evidenced by water quality conditions in ZL-136 (FEIS, p. 3-102).

Current Water Quality Conditions: Figure 3.3-17 shows the area of impacted surface and groundwater in Mill Gulch, based on the classification system described in Section 3.3.5. A summary of current conditions and post-1995 water quality trends is presented in Table 3.3-3. Trends in pH and sulfate for key downstream stations are provided in Figures 3.3-24 and 3.3-25.

*Current Surface Water Conditions:* The water quality indicators upgradient from the Mill Gulch capture system (L-35) were fairly steady from 1993 to 1997, with pH values around 4 s.u. and elevated sulfate (1,500 to 3,000 mg/l). At the capture system (L-36) pH values increase, ranging from 4 to 7 s.u., and sulfate decreases (400 to 1,500 mg/l). The improvement in water quality from L-35 to L-36 probably reflects the influence of groundwater inflow, which is generally of better quality at this location. Trend data for the capture system indicates decreasing pH and alkalinity, and increasing sulfate, TDS and metals. This area had the greatest number of total cyanide detections, with 14 detections equal to or greater than 0.01 mg/l.

Monitoring in a tributary drainage leading from the Landusky Mine process ponds was performed in 1997 and 1998. Based on data from L-8, water quality in this drainage represents neutralized ARD (Type 4), with cyanide detections and elevated nitrate. Lower Mill Gulch surface waters are monitored at spring L-22 and stream station L-7. The spring currently exhibits background water quality (2L) except for cyanide detections above 0.01 mg/l. There has been significant improvement since 1997. Just above the confluence with Rock Creek, Mill Gulch water quality is typical neutralized ARD, with a pH in the range of 7 to 8 s.u., sulfate ranging from 250 to 900 mg/l, and low metals. The range of these parameters is similar to those measured during 1995-96.

*Current Groundwater Quality Conditions:* Shallow groundwater quality near the toe of the Mill Gulch waste rock dump is ARD-impacted (Type 3), with low pH and alkalinity and high sulfate, TDS and metals. Trend data indicate decreasing pH and alkalinity, and increasing sulfate, TDS and metals during 1997-98. Deeper groundwater in bedrock beneath the toe of the waste rock dump is characteristic of naturally mineralized groundwater without ARD impacts or neutralized ARD indicators. Water quality parameters, including pH, alkalinity, sulfate, SC, and metals in the bedrock groundwater are all stable. Groundwater in the Landusky Mine process area is mine/ARD impacted with elevated sulfate, TDS, nitrate and cyanide. The pH and alkalinity is typically high and metal impacts are not observed. This is due to leakage from processing facilities.

Shallow bedrock groundwater quality in lower Mill Gulch is classified as a mixture of neutralized ARD with a rare occurrence of ARD indicators (Type 4/3), as evidenced by data from ZL-136. The most significant characteristic is the marked decline in TDS and sulfate since mid-1997 when the permanent capture system became effective. Recent data trends at this station indicate stable pH and alkalinity, decreasing sulfate and TDS, and no trend in metals concentrations. Groundwater in the alluvial aquifer (ZL-137, ZL-138) is typical of neutralized ARD water, with slightly elevated sulfate and TDS, and no metals, cyanide or nitrate impacts.

Based on the water balance results and average concentrations of parameters, the average annual sulfate and total metals loads were evaluated for each facility in the Landusky Mine (Spectrum 2000b). Mill Gulch contains approximately 35.5% of the total sulfate load, and 14.4% of the total metals load produced by the Landusky Mine, inclusive of leach pads and background loads. Excluding leach pads, Mill Gulch contains 12.1% of the total sulfate load, and 6.4% of the total metals load of the Landusky Mine.

## **Montana Gulch**

The Montana Gulch drainage is located on the southwestern side of the Landusky Mine (Figure 3.3-5). Mine facilities located within Montana Gulch include major portions of the L80-83, L84, and L85/86 leach pads and dikes, the majority of the Gold Bug pit backfill, portions of the August and Little Ben pits, the Montana Gulch waste rock dump, and the Landusky Mine water treatment plant. Facility locations are shown in Figure 3.3-5.

The upper Montana Gulch capture system became operational in 1997. It was designed to capture subsurface flows that originate primarily from within the recharge area of the main Landusky pit complex, the August drain tunnel, and the Montana Gulch waste rock dump. The lower Montana Gulch capture system became operational in 1997. It was designed to capture subsurface flows from the L85/86 leach pad underdrain, seepage not captured by the upper Montana Gulch system, and seepage from the L85/86 dike. The West Fork of Montana Gulch is blocked by the L85/86 leach pad, creating a small impoundment whose only outlet is a rock underdrain beneath the leach pad leading to the lower Montana Gulch capture system. Additional information on capture systems is contained in HSI and Gallagher (2001).

The Landusky Mine water treatment plant discharge comprises the majority of the baseflow in Montana Gulch. Impacted waters are present beneath much of the upper Montana Gulch drainage. Below the Landusky Mine water treatment plant outfall, a narrow band of neutralized ARD-type surface waters is present within the Montana Gulch alluvium, extending downstream to the confluence with Rock Creek.

### **Monitoring Stations**

*Surface Water:* Five new surface water monitoring stations were established for the Groundwater Study. The FEIS described water quality conditions at six stations (p. 3-77), while 18 stations were presented in the Groundwater Study (WMCI, pp. 290-292). Station locations are shown in Figure 3.3-23b. Many of the surface water stations were temporary stream gauging sites and have a limited period of record.

*Groundwater:* One new monitoring well, ZL-319, was completed in Devonian limestone downgradient from the L83 pad in Montana Gulch. A total of 19 wells, including the new well, were used in the Groundwater Study (WMCI, pp. 290-291). The FEIS evaluation utilized 11 of these wells (p. 3-102). Well locations are shown on Figure 3.3-23a. Additional information on surface and groundwater monitoring stations can be found in Gallagher (1999) and HSI and Gallagher (2001).

### **Water Quality**

*FEIS Surface Water Quality Conditions:* The FEIS identified impacts to surface water quality from the Montana Gulch waste rock dump, L84, L85/86, and L83 leach pads, and the Gold Bug pit (FEIS, pp. 3-77 to 3-81). Impacts to water quality were caused by a rupture in the L86 leach pad liner, a pipeline rupture below the L83 leach pad in 1992, construction of the leach pads, and seepage through the pits. The largest surface water discharge in Montana Gulch was from the Gold Bug adit (L-3). Although the discharge is entirely derived from groundwater, it was treated as surface water in the FEIS. The FEIS indicated a gradually worsening of water quality from the Gold Bug adit from 1979 to 1995, as evidenced by decreasing pH and increasing SC values (FEIS, p. 3-77). Surface water quality in lower Montana Gulch above the confluence with Rock Creek declined since baseline measurements in 1979, as evidenced by increasing sulfate, SC, and TDS concentrations at stations ZL-113 and ZL-114 (FEIS, p. 3-81).

*FEIS Groundwater Quality Conditions:* The FEIS concluded that Montana Gulch alluvial groundwater downgradient of the L85/86 leach pad has been degraded by ARD and cyanide contamination. These impacts are likely derived from the Montana Gulch waste rock dump, a breach in the L86 pad liner, discharges from the Gold Bug and August adits, and a leak in a process fluid line in 1992 (FEIS, p. 3-106). Alluvial groundwater was also affected by pre-ZMI mining activity at least as far downstream as the Montana Gulch campground, as evidenced by elevated arsenic concentrations from a now abandoned well at the campground (FEIS, p. 3-104). Groundwater in the limestones represents neutralized ARD, as evidenced by some cyanide detections, neutral pH, and low metals concentrations (FEIS, p. 3-104).

Current Water Quality Conditions: Figure 3.3-17 shows the area of impacted surface and groundwater in Montana Gulch, based on the classification system described in Section 3.3.5. A summary of current conditions and post-1995 water quality trends is presented in Table 3.3-3. Trends in pH and sulfate for key downstream stations are shown in Figures 3.3-24 and 3.3-25.

*Current Surface Water Quality Conditions:* The quality of water discharged from the Gold Bug adit declined from 1995 to 2000, as evidenced by decreasing pH values and increasing sulfate and SC concentrations. Since 1997, the Gold Bug discharge has been continuously collected and routed to the Landusky Mine water treatment plant prior to discharge into Montana Gulch. The water quality from the upper Montana Gulch capture system (L-38) has remained relatively static since 1997, exhibiting mild to moderate ARD conditions. Recharge through the Montana Gulch waste rock dump and the August drain tunnel discharge (now buried by this dump), and discharge from artesian well WS-3 report to the upper capture system. The August pit lake was drained in April 2000, but when sampled in October 1999, it was characteristic of Type 4, neutralized ARD, with slightly elevated manganese, nickel and zinc.

The lower Montana Gulch capture system operated from October 1997 to October 1998 when operations were temporarily discontinued. Results of monitoring confirmed that because most of the water reporting to this site originated in the undisturbed West Fork of Montana Gulch, the water quality of the lower Montana Gulch capture system was acceptable for surface discharge without treatment. Water captured by this system is periodically tested to determine whether the water is acceptable for release or if it must be sent to the Landusky Mine water treatment plant for treatment.

Discharge from the Landusky Mine water treatment plant (Station 591) continues to be good quality neutralized ARD water. Station 591 includes not only Landusky Mine water treatment plant discharge, but also overflow from the lower Montana Gulch capture system (L-17), which typically has not been pumped to the Landusky Mine water treatment plant since 1998. The quality of the treatment plant discharge generally improved in November 1999 with the initiation of the WS-3 aquifer test. The addition of water from WS-3 decreased TDS, sulfate and nitrate concentrations by about one-half in the plant discharge. Arsenic concentrations increased to a general range of 0.01 to 0.06 mg/l due to naturally higher levels in WS-3. Current surface water quality downgradient of the Landusky Mine water treatment plant outfall is classified as neutralized ARD, as evidenced by data from D-7 and L-2. Lower Montana Gulch exhibits gradually increasing sulfate and TDS, due to similar trends in the Gold Bug adit and water treatment plant discharge. Other mine contaminants, including metals and cyanide, have infrequently increased due to large runoff events.

*Current Groundwater Quality Conditions:* Groundwater quality in Montana Gulch is variable, depending on the location and depth monitored. Groundwater from the Gold Bug adit (L-3), beneath the Montana Gulch waste rock dump (L-38), and immediately downgradient of the L85/86 and L83 leach pad dikes (ZL-119) is ARD-impacted. Groundwater flowing from WS-3, which is recharged by the August pit and surrounding area, is typical of the naturally mineralized syenite aquifer (Type 2M). Although the reasons for the different water quality are not fully understood, WS-3 is open to the syenite aquifer at a depth from

286 to 369 feet below the typical static water level. As discussed in other sections, deeper groundwater beneath the Landusky Mine is typically not impacted by ARD, or is impacted to only a small degree.

Shallow groundwater quality below the water treatment plant outfall is not monitored, but would reflect that of the Montana Gulch baseflow (neutralized ARD) with occasionally elevated metals.

Based on the water balance results and average concentrations of parameters, average annual sulfate and total metals loads were evaluated for each facility in the Landusky Mine (Spectrum 2000b). Montana Gulch contains approximately 32% of the total sulfate load and 69% of the total metals load produced by the Landusky Mine, inclusive of leach pads and background loads. Excluding leach pads, Montana Gulch contains 71% of the total sulfate load and 74% of the total metals load in the groundwater at the Landusky Mine.

*The WS-3 Aquifer Tests:* Well WS-3, located in upper Montana Gulch, was drilled in 1984 as a supply well for dust suppression water at the Landusky Mine. It has a total depth of 243 feet in syenite porphyry and is cased to 160 feet below surface, with the remainder as uncased open borehole to 243 feet. When drilled, this artesian well yielded an estimated 1,000 gpm. Although never monitored, the flow reportedly tapered off to a couple hundred gpm. Through field experience and hydrogeologic evaluation, it became clear that WS-3 was connected to the Landusky Mine shear zone system. The well was closed and not used after late 1995. The last blasting in the August pit occurred on January 8, 1996. By the end of January, groundwater began to pond in the pit and continued to rise slowly to a maximum depth of about 15 feet.

On October 27, 1999, a test of WS-3 and the syenite aquifer was initiated. The well flowed continuously and unthrottled until November 6, 2000, at rates of 266 to 311 gpm. Discharge was collected by the capture systems and routed to the water treatment plant. The August pit lake began to decline approximately one week after the start of the test, and was completely dry by early April 2000. Periodic water level and water quality samples were collected from WS-3 and a network of wells around the Landusky Mine area.

On November 6, 2000, WS-3 was closed and a network of wells was measured for water level response. Groundwater levels responded within 30 to 45 minutes at the two closest wells (95LH-8, 95LH-9) lying along the strike of the shear zone. Other wells on the north side of the shear zone that are over 6,000 feet northeast of WS-3 (ZL-313, ZL-314) showed measurable recovery within 48 hours. Wells offset or outside the main shear zones showed a delayed response (ZL-206), or no response (ZL-317) in the first two weeks of recovery. The WS-3 tests demonstrate the dominance of the shear zones in controlling groundwater flow. The sustained discharge of WS-3 throughout the year is evidence of relatively large groundwater storage capability of the shear zone and associated underground workings. Even in a relatively dry year such as 2000, there was sufficient recharge in the pit area to keep groundwater levels stable throughout the summer and fall while the flow from the well was sustained. More information on the test is provided in HSI and Gallagher (2001).

Potentiometric surface maps (Figures 3.3-11 and 3.3-12) prepared for October 1999 (before the test) and October 2000 (near the end of test) illustrate that WS-3 is an effective tool in controlling groundwater levels in the Landusky pit area. The October 1999 map shows that with the August pit lake present, the groundwater divide zone probably cut through the lake. After WS-3 dewatered the pit, the groundwater divide zone shifted north through the Surprise and Queen Rose pits. Following the start of the test, water levels declined steadily until mid-May 2000 when at least two distinct recharge events led to temporary increases. When the test was terminated in November 2000, groundwater levels were estimated to lie 10 to 12 feet beneath the bottom of the August pit. Monitoring wells lying south of WS-3 in Paleozoic aquifers did not display any noticeable response to the year-long aquifer flow test. Additionally, the flow test of WS-3 did not measurably affect the flow of the Gold Bug adit. Since it is believed that these two points are hydraulically connected by shear zones, fractures and mine workings, it suggests that recharge to the area was great enough to supply the observed flows without much interference.

The water quality of WS-3 is classified as Type 2M, characteristic of the naturally mineralized zones of the syenite aquifer. The water has low TDS and near neutral pH, but elevated arsenic and iron. There was a slightly increasing SC trend and slightly declining trend in pH throughout the test. Remarkably, however, WS-3 did not develop ARD characteristics during the one-year test, unlike the Gold Bug adit and Montana Gulch waste rock dump located on either side of WS-3. Although the reason is not entirely clear, the fact that WS-3 is open to the deep portion of the syenite aquifer is the likely explanation.

### **Swift Gulch**

Swift Gulch is a headwaters tributary of South Big Horn Creek, located in the northeastern portion of the Landusky Mine area (Figure 3.3-5). Facilities located within the Swift Gulch drainage area include portions of the Surprise and Queen Rose pits and the Bighorn ramp fill (Figure 3.3-5).

ZMI submitted a Work Plan in January 1997 to address water quality concerns at monitoring site BKSS-1, located in a tributary to Swift Gulch. In response to detection of mine-impacted seepage at BKSS-1, ZMI removed and reclaimed a large-scale road fill (the Bighorn ramp) adjacent to and upgradient from the site. The project was completed in October 1996 and revegetation was established during 1997. In response to continued water quality concerns, evaluation of a passive treatment system is currently underway.

Water quality in Swift Gulch shows indications of increasing sulfate and TDS with a distinct upward trend since 1998 continuing through 2001. There are indications that the primary source of contaminants is seepage from the Surprise pit. Water quality below the Bighorn ramp is slightly improved since 1997; however, ARD impacts occur to Swift Gulch tributary drainages in response to runoff events.

Ferricretes, which are comprised of a framework of sediments cemented by red iron oxides, are found along both sides of the upper reaches of Swift Gulch. The ferricretes appear to be several thousand years old based on their position above the incised modern drainage. Erosion along the stream course has carried major portions of these ancient ferricrete sediments away. The recently precipitated ferric oxide on the streambed

of Swift Gulch and the ancient ferricrete blanket found along the shoulders of the drainage are essentially identical products of different ages of ferric oxide production and indicate that ferric oxide deposition can be a natural phenomenon unrelated to mining. This red, very fine silt-like sediment in Swift Gulch is forming within the same reach as the ancient ferricrete deposits, suggesting that its occurrence is normal for the natural setting.

Ferricrete deposits form in response to increased infiltration to the mineralized bedrock. In the prehistoric setting, this would have been due to increased precipitation. In the modern setting, their formation is likely due to increased infiltration through the mine pit floors. Capping of the pit backfill will decrease infiltration and reduce or halt ferricrete formation in Swift Gulch.

### **Monitoring Stations**

*Surface Water:* The FEIS used three monitoring stations to evaluate surface water quality in Swift Gulch and South Big Horn Creek (3-81). Since 1995, a number of new stations have been added. Nineteen Swift Gulch surface water stations and four South Big Horn stations were evaluated for the Groundwater Study (WMCI, pp. 326-328). Station locations are shown in Figure 3.3-23b. Many of the surface water stations were temporary gauging sites and have a limited period of record. Two of the original Swift Gulch stations, L-19 and L-20, are routinely monitored.

*Groundwater:* New Landusky pit complex wells completed upgradient of Swift Gulch include ZL-313, ZL-314, ZL-315, and ZL-316. With the exception of ZL-316, drilled in Precambrian gneiss, these deep wells are completed in syenite porphyry. A total of seven wells, including the four new wells, were used in the Groundwater Study evaluation. Swift Gulch groundwater is not described in the FEIS. Well locations are shown on Figure 3.3-23a.

### **Water Quality**

*FEIS Surface Water Quality Conditions:* The FEIS concluded there were impacts to Swift Gulch surface water quality from the Landusky Mine, as evidenced by rising concentrations of sulfate and hardness, and fluctuations in nitrate in samples from stations L-19 and L-20 (FEIS, p. 3-81). Despite rising sulfate and hardness concentrations since 1990, surface water in South Big Horn Creek is of good quality and not impacted by present or historic mining activity (FEIS, p. 3-86 and Table 3.2-32).

*FEIS Groundwater Quality Conditions:* No groundwater data were available during FEIS analysis. Surface water was assumed to reflect groundwater conditions.

**Current Water Quality Conditions:** Figure 3.3-17 shows the area of impacted surface and groundwater in the Swift Gulch, based on the classification system described in Section 3.3.5. A summary of current conditions and post-1995 water quality trends is presented in Table 3.3-3. Trends in pH and sulfate for key downstream stations are provided in Figures 3.3-24 and 3.3-25.

*Current Surface Water Quality Conditions:* Surface water baseflow just above South Big Horn Creek (L-49) and below the Surprise pit in Swift Gulch (L-19) exhibit water quality characteristics primarily associated with non-mineralized syenite porphyry with recent indications of neutralized ARD (Type 2NM/4). Mine-impacted waters are evident upgradient from station BKSS-14 with elevated sulfate and metals (arsenic, iron, manganese, nickel, and zinc). Iron hydroxide precipitates occur between BKSS-14 and L-19. The pH values throughout the creek were neutral in September 2001, with values ranging from 7.18 s.u. in South Bighorn Creek about 300 feet upstream of the Reservation boundary, to a low of 6.08 s.u. upgradient in the shear zone area of Swift Gulch. Since 1998, upward trends are also evident at L-19 in TDS, sulfate, iron and manganese, along with a slight downward trend in alkalinity; however, pH has been stable. Two small tributary drainages (stations BKSS-1 and BKSS-10), whose headwaters include the Bighorn ramp, are classified as ARD/mine impacted due to elevated TDS, nitrate and metals, along with low pH and alkalinity. Impacts appear to be associated with runoff events.

*Current Groundwater Quality Conditions:* Shallow groundwater in the area of the Surprise pit, Queen Rose pit and Bighorn ramp is ARD impacted (Type 3), as evidenced by low pH, elevated TDS, nitrate and metals in wells and springs that lie between the pits and Swift Gulch. The ARD impacts can be traced from the north rim of the Surprise pit (at ZL-315) to springs and seeps on the south side of Swift Gulch (BKSP-2E). ARD indicators at these stations have been increasing since 1997, demonstrated by declining pH and alkalinity, and increasing sulfate, TDS and zinc. The hydrogeologic data for this area show the Surprise shear zone is the primary mechanism for transport of ARD impacts from the pits to Swift Gulch.

Deep groundwater in the pit area (ZL-313, ZL-204, ZL-316), and groundwater discharge from the north (unmined) side of Swift Gulch (BKSP-2N) exhibits naturally mineralized groundwater quality with no ARD characteristics (Type 2M). This water quality type is distinguished by near neutral pH, SC less than 1,000 uS, alkalinity greater than 30 mg/l, elevated iron, arsenic, phosphorous and fluoride, but very low levels of cadmium, copper, nickel and zinc. The pH, alkalinity and metals are mostly stable in the deep groundwater. However, while TDS and sulfate remain near background levels, there is evidence of a slight upward trend in these parameters on the north side of the pit complex (ZL-313 and ZL-314). Deeper groundwater not directly downgradient of the pits does not exhibit this slight upward trend, as evidenced by data from ZL-204 and ZL-316.

Based on the water balance results and average concentrations of parameters, average annual sulfate and total metals loads were evaluated for each facility in the Landusky Mine (Spectrum 2000b). Inclusive of Landusky Mine leach pads, Swift Gulch contains approximately 0.6% of the total sulfate load and 0.1% of the total metals load. Exclusive of leach pads, total sulfate and total metals loads to Swift Gulch groundwater from the mine are approximately 1.9% and 0.15%, respectively. The loads include those from natural background.

## **King Creek**

King Creek is a headwaters tributary to South Big Horn Creek, located in the northwestern portion of the Landusky Mine (Figure 3.3-5). The August #2 waste rock dump is within the King Creek drainage. A major tailings removal project in King Creek was completed in October 2000 downstream of the Landusky Mine. This has removed a major source of sediment in the drainage. Water quality in upper King Creek generally represents neutralized ARD with low metals, but with elevated sulfate, TDS and nitrate levels.

The Consent Decree required installation of a capture system in King Creek. The system was required to capture impacted water, pump water to the water treatment plant, and return treated water to King Creek. ZMI installed a french drain collection system in King Creek in order to intercept shallow seepage, but did not complete the required system prior to bankruptcy. If continued monitoring of outfall #590 in King Creek indicates that compliance with MPDES standards still will not be achieved after the recent reclamation work, bond money is being retained so that a treatment system can be constructed.

### **Monitoring Stations**

*Surface Water:* Two monitoring stations were used to evaluate conditions in King Creek for the FEIS (p. 3-81). The five stations used for interpretations in the Groundwater Study included these two stations and three additional sites (WMCI, pp. 326-328). Station locations are shown in Figure 3.3-23b. Many of the surface water stations were temporary gauging sites and have a limited period of record. One station located at the Reservation boundary (L-39) is routinely monitored.

*Groundwater:* Four new wells, ZL-303, ZL-305, ZL-307, and ZL-317, and two piezometers, ZL-304 and ZL-306, were installed in King Creek. A total of nine wells, including the six new completions, were used in the Groundwater Study evaluation. The FEIS evaluation used two of these wells. Well locations are shown on Figure 3.3-23a.

Detailed information regarding surface and groundwater stations can be found in WMCI (1998), Gallagher (1999) and HSI and Gallagher (2001).

### **Water Quality**

*FEIS Surface Water Quality Conditions:* The FEIS concluded there were minimal impacts from historic mining in King Creek at the time ZMI began large-scale mining (FEIS, p. 3-81). However, Upper King Creek surface water quality had been progressively affected by mining activities since 1979 (FEIS, p. 3-86). Increased nitrate levels in surface waters (L-5) are derived from reclamation efforts in the headwaters or the use of blasting agents. Removal of historic tailings during 1993 has reduced the total suspended solids concentration of surface waters (FEIS, p. 3-86).

*FEIS Groundwater Quality Conditions:* Alluvial groundwater in King Creek was impacted by mining activities, as shown by slightly elevated nitrate concentrations at ZL-140. Syenite bedrock groundwater had elevated TDS, SC, sulfate and nitrate levels, but a consistently neutral pH (ZL-139), indicating mining-related impacts (FEIS, p. 3-104).

Current Water Quality Conditions: Figure 3.3-17 shows the area of impacted surface and groundwater in King Creek, based on the classification system described in Section 3.3.5. A summary of post-1995 water quality trends is presented in Table 3.3-3. Trends in pH and sulfate for key downstream stations are provided in Figures 3.3-24 and 3.3-25.

*Current Surface Water Quality Conditions:* With the exception of the headwaters area, the main stem of King Creek does not exhibit significant impacts to surface water quality from the Landusky Mine. Water quality in the headwaters area close to the mine is typical of neutralized ARD, as evidenced by elevated sulfate, TDS and nitrate levels at station L-5. The metals cadmium, manganese and zinc are also slightly elevated. The principal source of these impacts is the August #2 waste rock dump. Dilution by unimpacted water leads to gradual improvement in water quality in the downstream direction. Water quality at the Reservation boundary (L-39) is typical of non-mineralized water and is classified as Type 2NM/5. The secondary Type 5 is due to occasional slightly elevated metals, nitrate and selenium. Trend data show that water quality has been improving since 1997, with stable pH, sulfate and TDS, increasing alkalinity, and decreasing nitrate concentrations.

*Current Groundwater Quality Conditions:* Shallow groundwater (less than 40 feet) in King Creek is typical of neutralized ARD (Type 4), as evidenced by elevated TDS and sulfate at ZL-139. In addition, nitrate is elevated, probably due to residual blasting agents and fertilizer used on the August #2 waste rock dump. Trend data indicate generally stable pH, alkalinity, TDS, and sulfate, with stable, low metals concentrations. Groundwater quality as deep as 80 feet exhibits neutralized ARD quality and elevated nitrate (ZL-303). Groundwater quality in the deeper aquifer (145-165 feet bgl) is representative of background non-mineralized syenite aquifer water (Type 2NM), as evidenced by data from ZL-307. Monitoring of wells installed in the Groundwater Study led to the conclusion that a groundwater divide exists between the Landusky pit complex and King Creek (WMCI, p. 198). This has been confirmed by additional water level measurements from 1997 to 2000.

Based on the water balance results and average concentrations of parameters, average annual sulfate and total metals loads were evaluated for each facility at the Landusky Mine (Spectrum 2000b). King Creek contains approximately 0.6% of the total sulfate load, and 0.04% of the total metals load produced by the Landusky Mine. Excluding leach pads, the sulfate and metals loads to King Creek groundwater from the mine are estimated at 1.85% and 0.05%, respectively.

**Table 3.3-3. Current Water Quality Conditions and Trends in Landusky Drainage Basins**

Drainage	Area Summary	Station Type	Current Conditions	Trends				Remarks
				pH	Alkalinity	Sulfate/SC	Metals	
Sullivan Gulch	Above capture system	Source	3	-	-	+	+	Alluvial and bedrock groundwater contaminated
	Below capture system	Down-gradient	2NM	sl +	sl +	sl +	stable to sl +	Station D-4, above Rock Creek
Rock Creek	Sullivan to Mill Gulch	Down-gradient	2NM, 2L	stable	stable	stable	no trend- low	
	Below Mill Gulch	Down-gradient	4	stable	stable	+	no trend	
Mill Gulch	Rock dump to capture system	Source	3	- to stable	- to stable	+ to stable	+	Capture system moved and deepened in late 1997
	Below capture system	Down-gradient	2NM/3	sl + to stable	stable to sl +	-	no trend, low	
Montana Gulch	Mine area/pits	Source	3, 2M	-	- to no trend	+	+	Gold Bug and L-38 declining quality WS-3 non-ARD, stable- slight decline
	Lower leach pads	Down-gradient	3	stable	sl +	+	no trend, variable	Mine impacts due to cyanide, metals and elevated sulfate
	Below mine	Down-gradient	4	stable	stable	+	no trend variable	Trends affected by Gold Bug and Landusky water treatment plant
Swift Gulch	Mine area/pits	Source	3/2M	-	sl -	+	no trend sl +	ARD impacts to shallow groundwater
	Creek	Down-gradient	2M, 2NM	stable	sl -	0	elevated Fe, Mn, and Zn	Increasing trend of neutralized ARD parameters since 1998. Water quality is mix of unmineralized, natural mineralized and mine-impacted waters.
King Creek	Headwaters rock dump	Source	4	stable	stable	+	+	
	Near Reservation	Down-gradient	2NM/4	stable	stable sl +	stable	no trend- stable	Improving water quality- increasing alkalinity, declining metals, nitrate

Current Conditions: 1=Headwaters Background; 2M=Mineralized Syenite Background; 2NM=Non-Mineralized Syenite Background; 2L=Limestone Background; 3=Mine/ARD Impacted; 4=Neutralized ARD; 5=Various Mine-Related Indicators. Trends: + increasing; - decreasing; sl=slight

### **3.3.8 Madison Group Aquifer**

The Madison Group, comprised of the Mission Canyon and Lodgepole Formations, is a dominant feature of the Little Rocky Mountains. These limestones flank the majority of the range and serve as the current water supply source for the town of Zortman, and a potential water supply source for the Hays/White Cow area of the Fort Belknap Reservation (information on community water supplies is in Section 3.3.9).

For the purposes of analysis, the Madison Group is divided into the local unit and the regional unit. The local unit consists of the flanking, exposed limestones of the Madison Group. The regional unit consists of the buried Madison Group. Oil and gas well logs show the Madison Group is buried up to 2,000 feet beneath the surface a short distance from the Little Rocky Mountains. The units are also differentiated by water chemistry and temperature. Water discharging from the regional unit is warm (over 20°C warmer than the local unit) and contains significantly more sulfate than the local unit.

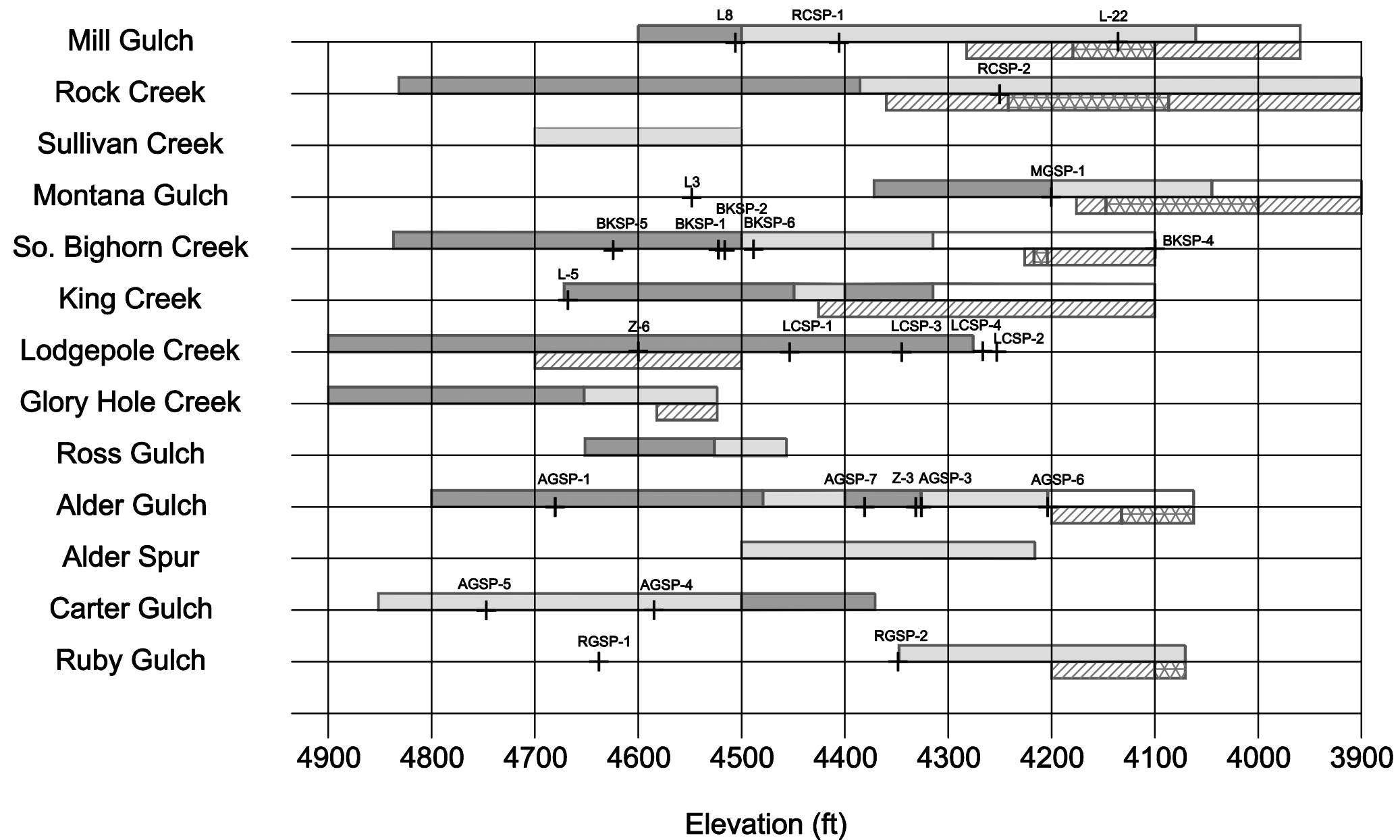
The regional and local units meet at the base of the Little Rocky Mountains where several warm springs discharge. These include Big and Little Warm Springs to the northeast, and Mud Creek Springs and “The Plunge” to the southwest. These springs also have a component of recharge from the local unit, which becomes particularly apparent during large precipitation events (Feltis 1983).

#### **Groundwater Flow**

Most groundwater recharge to the local Madison Group aquifer results from surface water, rather than movement between aquifer units (WMCI, p. 184). Recharge occurs across the Madison Group in the drainages where vertical gradients are downward. As shown in Figure 3.3-26, Alder Gulch loses water across the Madison Group, indicating a downward vertical gradient. Streamflow in Ruby Gulch was stable across the Madison Group, despite the vertical downward gradient indicated by paired wells. In the Landusky Mine area, Rock Creek and, to a lesser degree, Mill Gulch exhibit upward vertical gradients across the Madison Group. Surveys show Montana Gulch loses water over the Madison Group outcrop.

Groundwater flow within the Madison Group is typically lateral through karstified bedding planes and fractures along the range front toward the lowest elevation outcrop of the formation (Gallagher 1999). High conductivity zones within the Mission Canyon member of the Madison Formation appear to be associated with karst solution channels within the limestone, as the largest producing wells in the Madison are associated with such features. Many of these solution channels are infilled with clay, greatly reducing the effective hydraulic conductivity of these features.

However, where these karstic features are encountered in the Mission Canyon limestone below the flat slopes surrounding the Little Rocky Mountains, they appear to remain partially open and can produce significant quantities of water. These karstic features, however, appear to be limited in extent, as evidenced by declining yields in wells completed in these features over time (WMCI, p. 194). Additional information regarding the Madison Group aquifer can be found in Gallagher (1999) at pp. 71-82.



#### LEGEND

	Gaining Reach		Sedimentary Rocks (except Madison Formation)		Madison Formation		Spring
	Stable Reach						
	Losing Reach						

NOTE: The section in lower Rock Creek below station L-23 has been noted as a stable reach due to recent data, but is probably more properly characterized under normal flow conditions as a losing reach followed by a gaining reach due to circulation of groundwater through the alluvium along the stream channel.

## GAINING, LOSING, AND STABLE REACHES OF MINE SITE DRAINAGES

Source: Water Management Consultants, 1998

FIGURE 3.3-26

## **Current Conditions**

Impacts to the Madison Group aquifer from the mine sites only result from infiltration of mine-influenced surface water and associated alluvial groundwater near drainage bottoms where steeply dipping beds of Madison Group are exposed (WMCI, p. 530). Some impacts to alluvial groundwater and shallow alluvial-recharged limestone aquifers from ARD and process water contamination are evident near the town of Zortman. These impacts are evident in well ZL-142, which is screened across the alluvium and uppermost Madison aquifer, and include elevated sulfate concentrations. Trace levels of total cyanide were detected in this well on several occasions from 1990 through 1998; however, these were below the accepted significance level of 0.01 mg/l. In the deep Madison well ZL-312, water quality generally resembles the background limestone type. However, elevated arsenic and occasionally elevated sulfate have been identified in samples from this well. Monitoring well ZL-312 is screened over a section of mineralized limestone. At the Landusky Mine, infiltration immediately downstream of the L80/82 and L83 leach pads may have impacted Madison Group limestone water quality.

No mining-related impacts are evident at peripheral springs (e.g. Little and Big Warm Springs) of the Little Rocky Mountains. In order for the Madison Group aquifer to be impacted on the Reservation from the Landusky Mine site, contaminated water would have to travel northward down South Big Horn Creek and Little Peoples Creek to the Madison outcrop in Little Peoples Creek approximately 1.5 miles downstream. From the Zortman Mine site, contaminated water would have to travel about 3 to 4 miles to the Madison outcrops in the Lodgepole Creek drainage. Gallagher (1999) found that it is unlikely the flanking Madison Group aquifer would be affected by the mines.

### **3.3.9 Beneficial Use**

#### **Surface Water Use**

##### **Zortman Area**

##### Water Quality

Ruby Gulch and Alder Gulch and their tributaries in the area of discharge are classified as "C-3" [ARM 17.30.610(5)]. Waters classified "C-3" are considered suitable for bathing, swimming, and recreation, growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers. The quality of these waters is naturally marginal for drinking, culinary and food processing purposes, agricultural and industrial water supply. Ruby Gulch from the headwaters to one mile below the town of Zortman is listed on Montana's 1996 303(d) list as impaired due to metals, pH, flow alteration, and other habitat alteration. Alder Spur and Carter Gulch, both tributaries of Alder Gulch, are also on the 1996 Montana 303(d) list as impaired due to metals, suspended solids and pH.

Peoples Creek, which includes Lodgepole Creek and its tributaries (Glory Hole Creek and Ross Gulch), is classified as “B-1” [ARM 17.30.610(8)(d)]. Waters classified as “B-1” are considered suitable for drinking, culinary, and food processing purposes, agricultural and industrial water supply, and those uses listed above for “C-3” waters. Neither Lodgepole Creek nor its tributaries are listed on the 1996 Montana 303(d) list. The probable causes for all areas on the 303(d) list is resource extraction.

#### Water Quantity

The 1996 FEIS reported little information regarding the impact of past mining operations on surface water flows in the Lodgepole Creek drainage (FEIS, p. 3-109). Since 1987, no changes in flow have been identified in any northern drainages.

### **Landusky Area**

#### Water Quality

Rock Creek and its tributaries (Montana Gulch, Mill Gulch, and Sullivan Gulch) in the area of discharge are classified as “C-3” [ARM 17.30.610(5)]. Waters classified “C-3” are considered suitable for bathing, swimming, and recreation, growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers. The quality of these waters is naturally marginal for drinking, culinary and food processing purposes, agricultural and industrial water supply. Segments of Rock Creek, in the area of discharges, is listed on Montana’s 1996 303(d) list (including Mill Gulch, Sullivan Creek, and a portion of Rock Creek). Causes for impairment in Mill Gulch and Sullivan Creek are metals and pH. Metals, nutrients, and other habitat alterations are causes for impairment in Rock Creek.

Swift Gulch and King Creek are located in the Peoples Creek drainage and are classified as “B-1” [ARM 17.30.610(8)(d)]. Waters classified as “B-1” are considered suitable for drinking, culinary, and food-processing purposes, agricultural and industrial water supply, and those uses listed above for “C-3” waters. Swift Gulch is a tributary to Big Horn Creek, which in the vicinity of Swift Gulch, is listed on the 1996 Montana 303(d) list. The probable cause for impairment is metals concentrations. King Creek in the area of the discharge is also listed on the 1996 Montana 303(d) list. The probable causes of impairment include metals and other habitat alteration. The probable causes for all areas on the 303(d) list is resource extraction. Additional information on Landusky surface water quality is presented in Section 3.3.10 under TMDLs.

#### Water Quantity

The 1996 FEIS reported little information regarding the impact of mining operations on surface water flows in the Little Peoples Creek drainage (FEIS, p. 3-109). Data from Little Peoples Creek flow gauging (near Hays) indicated an initial decrease in flow between 1978 and 1980 (FEIS, p. 3-113). Since 1987, no changes in flow were identified in any northern drainages.

Although monitoring data are not available, it is likely that surface water flow and spring discharge to the north of the Landusky Mine would have decreased when the August and Gold Bug adits were completed in the 1960s, effectively diverting a large percentage of the catchment to the south (FEIS, p. 3-113).

The Final Report on the Landusky Mine Hydrologic Impact to King Creek and Swift Gulch (Spectrum 2000c) concluded that King Creek lost an estimated 16.1 million gallons per year (31 gpm), while Swift Gulch gained 13.6 million gallons per year (26 gpm) from pre-mine conditions to present due to mining activities. This estimate is based on the assumption that the pre-mine surface water and groundwater basins were coincident, and that artesian well WS-3 was closed. The report did not differentiate how much of the loss is attributable to the underground workings and how much is due to the present day open pit. Combining the gains and losses in King Creek and Swift Gulch shows that an overall loss of 2.5 million gallons per year (or 5 gpm) occurs with artesian well WS-3 closed.

However, due to concerns about water quality beneath the Landusky pits migrating north, well WS-3 is to be left open in the foreseeable future. To account for this condition an addendum to the Final Report on the Landusky Mine's Hydrologic Impact to King and Swift Gulch was prepared (Spectrum, 2001c). This addendum reevaluates the change in flow values for King Creek and Swift Gulch due to the effects from well WS-3 flowing unthrottled and from the lining of the Surprise and Queen Rose pit floors as part of interim reclamation. The addendum study concludes that compared to pre-mining conditions, the estimated total loss of surface water and groundwater discharge to King Creek and Swift Gulch combined would be 64 to 76 gpm. This is probably a worse case estimate since it is based on water balance criteria developed for a wetter than normal year (1998), and it assumes that all of the infiltration falling over the capture zone of WS-3 actually reaches WS-3. Perched groundwater discharge to King Creek and Swift Gulch above the shallow/intermediate syenite aquifer is known to occur, but was not considered in the addendum analysis. Inclusion of the water held in the perched system would reduce the estimated loss.

## **Groundwater Use**

### **Community Water Supplies**

Domestic water supplies in the communities of Zortman and Landusky depend entirely on groundwater. An updated list of groundwater rights in the Zortman and Landusky area are presented in HSI and Gallagher (2001).

*Zortman:* The town of Zortman is served by a deep well (Z-8A) completed in the Madison Group limestone. This well was constructed in 1982 after mining activities impacted domestic water supplies for Zortman that were located in the Alder Gulch alluvium. Z-8A has been monitored since 1982 and has shown no indications of mine-related contamination. The primary water quality concern for Z-8A would be from mine-impacted surface water infiltrating to the Madison Group aquifer in lower Ruby Gulch.

However, the geology of the area, including significant structure and low permeability rocks between the town well and the Ruby Gulch drainage, limits the potential for impacts to Z-8A from Ruby Gulch. Geology of this area is described in detail in Gallagher (1999). At present, the community is trying to obtain funds to improve the water distribution system. Many of the pipelines in this system are constructed in the historic Ruby tailings which are unstable during large runoff events, leading to ruptured lines.

*Landusky:* Few logs exist for Landusky townsite wells. However, most of the town wells are completed in both alluvium and underlying bedrock (WMCI, p. 166). Impacts to the Landusky alluvial groundwater (TP-series domestic wells) have resulted from discharges from the Mill Gulch waste rock dump, as evidenced by high TDS and sulfate waters in the alluvium above the Landusky townsite. Also, minor and transient groundwater impacts have occurred from past releases in Sullivan Gulch, evidenced by slightly elevated and transient concentrations of arsenic, lead and manganese (WMCI, p. 538). No cyanide has been detected in Landusky wells. Impacted water from Mill Gulch and Sullivan Gulch is currently captured and pumped to the Landusky Mine water treatment plant. Only a small portion of the runoff from infrequent large storms and snowmelt events escapes capture and treatment.

Data collected since 1995 indicate water quality in some of the Landusky domestic wells (TP-series) has been affected by mine activities. Using the water classification system, alluvial water quality in Mill Gulch above the confluence with Rock Creek (TP-1), is representative of neutralized ARD with elevated SC, sulfate, and nitrate (Type 4). Data from TP-2 show an upward sulfate trend, while alkalinity is declining. The alluvial groundwater also shows erratic, but often high iron concentrations (up to 6 mg/l). This water quality is a mixed type representing neutralized ARD from Mill Gulch diluted by less affected Rock Creek water (Type 2L/5). With the exception of periodically elevated iron concentrations, alluvial water quality in Rock Creek above the town of Landusky does not appear to be significantly different than 1995 values, as evidenced by data from TP-3 (Type 2L). Data show that shallow groundwater in Landusky appears to be influenced by runoff events, as evidenced by a high degree of fluctuations in water quality parameters during wet periods.

Bottled water has been supplied to the residents of Landusky since 1993. Testing of eight Landusky domestic wells in the fall of 2000 showed that water quality meets primary drinking water standards. Resampling of these wells in the spring of 2001 also showed the well water met drinking water standards and supplying bottled water to Landusky residents was discontinued.

Two test wells, LNDWS-1 and LNDWS-2, were drilled, but never developed, south of the Landusky townsite. The wells were drilled to locate a community water supply for Landusky. The target aquifer was the Madison Group. However, the wells were drilled to over 400 feet without reaching the top of the Madison, and were screened in what appears to be Jurassic-aged sandstones and siltstones. The wells produced about 35-40 gpm during drilling. Water quality analyses indicated sulfate-rich waters typical of other sandstone, without indications of mine-related contaminants.

*Fort Belknap Reservation:* Several hydrogeology studies have been completed on the Fort Belknap Reservation by the U.S. Geological Survey and Montana Bureau of Mines and Geology, including Feltis (1983), Slagle (1993) and Briar and Oellermann (1993). The studies found that natural water quality on the Reservation in aquifers away from the mountain front is naturally variable and often quite poor. None of the studies cited mine activities as contributing to the poor quality of the area aquifers.

The Madison Group has the best water quality in the Hays area, but only from wells located close to the Little Rocky Mountain front. A short distance from the mountains, the Madison dips steeply away from the range and is generally located at depths uneconomic for water supply development. Additionally, the deeper regional Madison Group aquifer is moderately mineralized (2,000 to 2,500 mg/l TDS) and warm (30 to 40°C) (values based on maps contained in Downey and Dinwiddie (1988)). The USGS constructed five wells in the Madison Aquifer, including two located in Mission Canyon towards the Landusky Mine and three along the range front near Mission Canyon. Analytical results indicate that water quality meets all the Federal primary and secondary drinking water standards (Slagle 1993).

As part of the Consent Decree settlement, ZMI agreed to complete a water system improvement project for Hays. Two exploration wells (WSIP-1 and WSIP-2) were drilled in the Madison Group aquifer north of Mission Canyon along the range front. Results of drilling indicated that a 250 gpm, good quality water supply well could be developed. Due to the ZMI bankruptcy, this project was not completed; however, monies were provided to Fort Belknap for water system improvements.

Both the FEIS and the Groundwater Study conclude that the only significant source of contamination to the Reservation would be by the recharge of contaminated surface water to permeable sedimentary formations (i.e. the Madison Group) exposed in the stream channel. While mining-related contaminants have been identified in the headwaters of Swift Gulch and King Creek, tributaries to Little Peoples Creek, the monitoring data indicate that with the exception of selenium, water quality standards are met at the upstream Reservation boundary. Selenium concentrations slightly exceed state water quality standards. This is due primarily to dilution from water contributing to the stream between the mine and the Reservation. The Groundwater Study and additional monitoring since 1996 demonstrate that the much of the elevated iron, manganese, arsenic, fluoride and phosphorous in the headwaters of Swift Gulch and King Creek is caused by the natural mineralization of the area. Ongoing surface water monitoring in Little Peoples Creek upgradient from the mouth of Mission Canyon is maintained in order to identify water that has the potential to impact the domestic water supply.

The ATSDR study concluded that based on a review of the data, there is no apparent public health hazard to the residents of Fort Belknap. The data provided no evidence that people have been, or are being exposed to dangerous levels of environmental contamination in sediments, surface water or groundwater located within the boundaries of the Reservation (ATSDR 1998).

The EPA conducted groundwater sampling of 15 wells on the Fort Belknap Indian Reservation and three wells in the town of Zortman on June 13-15, 2000. The wells included selected public and private water

supply wells and monitoring wells. Based on the water classification system discussed earlier, none of the wells have mine-related impacts. The pH in all wells was greater than 7 s.u., and alkalinity was 220 mg/l or greater in the wells sampled on the Reservation. Alkalinity of the Zortman townsite wells was 180 mg/l. Sulfate concentrations were less than 400 mg/l in all but one well, ZDW-GW-14, which is located approximately 3.6 miles northwest of Hays, Montana. This well had a high pH (8.81 s.u.), and is likely completed in Cretaceous sandstone or shale.

The water sampling results were reviewed relative to primary or secondary state standards for groundwater. Well ZDW-GW-04 slightly exceeded the copper standard. This well is not in a drainage potentially impacted by either of the mines. Four wells, ZDW-GW-04, ZDW-GW-06, ZDW-GW-13 and ZDW-GW-17 exceeded the secondary standards for iron and/or manganese. Elevated iron and manganese in groundwater is a common occurrence and not related to affects from the mines.

### **3.3.10 Regulatory Criteria**

As noted in the FEIS (p. 3-113), the Montana Water Quality Act (§75-5-402, MCA) requires a Montana Pollutant Discharge Elimination System (MPDES) permit for any discharge of sewage, industrial wastes, or other wastes to state waters. MPDES permits have established effluent limits, calculated to meet the water quality standards of a water body. Current effluent limits for discharge from the water treatment plants are based on the Consent Decree requirements. A copy of the MDPES discharge permits is in Appendix C.

Surface water classifications and uses for each drainage are described in Section 3.3.9. Types and causes of water quality impairments to drainages are described in more detail in the following TMDL section.

### **Total Maximum Daily Loads (TMDLs)**

The term “TMDL” stands for Total Maximum Daily Load and originated in the Federal Clean Water Act of 1972. In the years since 1972, the meaning of the term has evolved to include many water quality-related conditions besides the total maximum load of pollutants in a water body. Today, the term TMDL refers to the overall strategy for bringing polluted waters into compliance with standards.

Section 303(d) of the federal Clean Water Act requires states to prepare a list of water bodies not supporting their designated beneficial uses, and submit it to EPA for review and approval every two years. The DEQ Monitoring and Data Management Bureau is the agency responsible for developing the list, which is referred to as the “List of Waterbodies in Need of Total Maximum Daily Load Development.” In 1996 Montana Gulch, Mill Gulch, Alder Gulch, Ruby Creek, Rock Creek, Sullivan Creek, King Creek and Big Horn Creek were on the Montana “List of Waterbodies in Need of Total Maximum Daily Load Development.”

Montana Gulch was listed as not supporting the beneficial uses of aquatic life support, cold water fishery, drinking water supply and swimming in 1996. The probable causes of impairment were metals from resource extraction and subsurface mining.

Mill Gulch was listed as not supporting the beneficial uses of aquatic life support, drinking water supply, swimming and warm water fishery. The probable causes of impairment were metals and pH from resource extraction and subsurface mining.

Alder Gulch was listed as not supporting the beneficial uses of aquatic life support, cold water fishery, drinking water supply and swimming. The probable causes of impairment were metals, suspended solids and pH from resource extraction and surface mining.

Ruby Creek from the headwaters to one mile below the town of Zortman was listed as not supporting the beneficial uses of aquatic life support, drinking water supply, swimming and warm water fishery. The probable causes of impairment were flow alteration, metals, habitat alterations and pH from resource extraction and surface mining.

Rock Creek near Landusky was listed as partially supporting the beneficial uses of aquatic life support and warm water fishery. It was listed as not supporting the beneficial use of drinking water supply. The probable causes of impairment were metals, nutrients and habitat alterations from resource extraction, agriculture and range land.

Sullivan Creek was listed as not supporting the beneficial uses of aquatic life support, drinking water supply, swimming and warm water fishery. The probable causes of impairment were metals and pH from resource extraction and surface mining.

King Creek was listed as partially supporting the beneficial uses of aquatic life support and cold water fishery. Moreover, it was listed as not supporting the beneficial use of drinking water supply. The probable causes of impairment were metals and habitat alterations from resource extraction activities.

Big Horn Creek was listed as partially supporting the beneficial uses of aquatic life support, cold water fishery, drinking water supply and swimming. The probable causes were metals from resource extraction activities.

In 1997, the Montana Legislature amended the Montana Water Quality Act (§75-5-701 through 75-5-705, MCA) clarifying the authority of DEQ to monitor water quality and bring Montana's water resources into compliance with water quality standards through the TMDL process. The legislation required a comprehensive review of listed waters by 1999 and completion of TMDLs for all waters on the 1996 303(d) list by 2007.

DEQ completed the comprehensive review of listed waters in late 1999 and the results are published in the 2000 303(d) list. The comprehensive review involved collecting water quality data from all State, Federal and local agencies to determine if there was sufficient and credible data to warrant listing an impairment of a water body. Montana Gulch, Alder Gulch, Ruby Gulch, Rock Creek, Mill Gulch, and King Creek had sufficient and credible data to determine an impairment. Sullivan and Big Horn Creeks did not meet the sufficient and credible data. DEQ plans to reassess these drainages as new information becomes available.

Montana Gulch (headwaters to mouth) is listed on the 2000 list as not supporting the beneficial uses of aquatic life support, cold and warm water fishery. The probable causes of impairment are metals, arsenic, copper, zinc and pH from acid mine drainage and abandoned mining.

Alder Gulch (headwaters to Ruby Creek) is listed in 2000 as partially supporting the beneficial uses of aquatic life support and cold and warm water fishery. The probable causes of impairment are metals, nitrate, pH and habitat alterations from resource extraction, mine tailings, acid mine drainage and abandoned mining.

Ruby Gulch (headwaters to one mile below Zortman) is listed in 2000 as partially supporting the beneficial use of aquatic life support. Probable causes of impairment are metals and pH from resource extraction and abandoned mining.

Rock Creek (headwaters to Missouri River) is listed in 2000 as partially supporting the beneficial uses of aquatic life support and swimming. Probable causes are metals, pH and riparian degradation from resource extraction, inactive mining, and grazing.

Mill Gulch is listed in 2000 as partially supporting the beneficial uses of aquatic life support, warm water fishery and swimming. Probable causes are metals, nitrate, pH and riparian degradation from resource extraction, surface mining and grazing.

King Creek is listed in 2000 as partially supporting aquatic life and cold water fishery. It is listed as not supporting the beneficial uses of drinking water, swimming, and use by agriculture and industry. Probable causes are metals, nitrate, siltation, and habitat alterations from mine tailings and abandoned mining activity.

All alternatives addressed in the SEIS are intended to meet the minimum requirements for a TMDL. The potential differences among the alternatives in achieving varying degrees of water quality restoration from recent mining activities is addressed in Chapter 4.

### **3.3.11 Summary of Findings**

The following list contains the most significant findings related to the water resources and geochemistry of the Zortman and Landusky Mines since preparation of the 1996 FEIS.

- The concepts of the geochemical evolution and maturation of waste rock dumps, dikes and leach pads were developed for specific facilities at each mine. A few facilities at the Zortman Mine have likely reached maturity, but most, including all at the Landusky Mine have not. Reclamation would lessen ARD impacts, but the acid generation process cannot be halted entirely. Water quality within most mine facilities may continue to worsen for a long period, estimated to range from 10's to 100's of years.
- Since 1995, many new wells were installed for the Groundwater Study, which permitted more detailed evaluations of the direction of groundwater flow, definition of groundwater divide zones, and water quality monitoring to define impacts from the mines in space and time. The hydrogeologic interpretations made from these data have allowed a much better understanding of the hydrology and water chemistry at both mines and the surrounding area. For instance, data collected during, and subsequent to the Groundwater Study indicate the majority of groundwater from the mine sites flows along shallow and intermediate flowpaths that discharge to capture systems and surface water within the syenite porphyry aquifer. There does not appear to be a significant deep flowpath.
- Water balances for every facility or basin on both mines were computed using 1997-1999 daily flow records from the new, permanent capture systems, along with mine precipitation data. The capture systems allowed entire waste rock dumps and dikes to be evaluated as huge lysimeters, enabling direct estimates of on-site groundwater recharge and evapotranspiration. Direct calculations of recharge rates to leach pads were made using weekly sump measurements and mine precipitation data. Computed recharge rates were much higher and evapotranspiration was lower than previous estimates. Recharge rates ranged from 45 to 49% on reclaimed waste rock dumps and pads, and 69 to 71% on unreclaimed leach pads. The capture systems were found to be very efficient collectors of contaminated surface water and groundwater runoff from mine facilities and have greatly reduced impacts to water quality.
- Using the water balances and recent water quality data, total annual loads of sulfate and total metals were computed for all mine facilities. This enabled development of estimates of contaminant loads to drainages, and determination of the fate of these contaminants. For the Zortman Mine, it was found that 66% of the sulfate load and 78% of the metals load was collected and sent to the water treatment plant, 31% of the sulfate load and 18% of the metals load was sent to the Goslin LAD, and 3% of the sulfate load and 4% of the metals load reported to uncaptured groundwater. For the Landusky Mine, it was found that 24% of the sulfate load and 80% of the metals load was collected and sent to the water treatment plant, 66% of the sulfate load and 18% of the metals load was sent to the Goslin LAD, and 10% of the sulfate load and 3% of the metals load reported to uncaptured groundwater and surface baseflow (Spectrum 2000a and 2000b).
- Not all of the mine facilities assumed in the 1996 FEIS to be acid generating are so. The Z83, Z84, and Z89 leach pads are near neutral, as are the L80 through L84 leach pads. The L85/86

leach pad is suitable for use as non-acid generating material in construction of the reclamation covers.

- Geochemical characterization shows there is a large quantity of ARD contaminants stored within the mine facilities. For example, at the Landusky Mine, if all further sulfide oxidation could be eliminated, water treatment would need to be continued for approximately 150 years to treat the estimated quantity of contaminants currently stored in the spent ore and waste rock.
- New evaluations of the massive water quality data base for the mines, along with comprehensive hydrogeologic interpretations, led to the development of an empirical Water Quality Classification System. Nearly 800 samples from over 100 stations were classified as natural or mine-impacted. The interpretive map prepared from the classifications was used to depict the extent of mine impacts on shallow groundwater and surface water baseflow.
- Mine-impacted water quality at the Zortman Mine is worse than that at the Landusky Mine, but the extent and magnitude of off-site impacts of the Zortman Mine appear stable for the most part. Although the Landusky Mine ARD is not currently as strong, the extent of the off-site impacts is greater, and the impacts appear to be worsening since 1995 in most of the drainages. Swift Gulch, in particular, has experienced worsening water quality since 1997. King Creek is an exception, and appears to be slightly improving.
- A year-long test of artesian well WS-3 on the Landusky Mine demonstrated that it could be used very effectively to drain the August pit lake and control groundwater levels throughout the shear zone of the Landusky Mine. The aquifer test confirmed the high permeability and storage capacity of the shear zone, and that groundwater outside the shear zone in syenite or Paleozoic aquifers is relatively isolated from that in the shear zone. The water quality of WS-3 declined slightly during the test but remained unimpacted by ARD.
- Operation of the Goslin Flats LAD began in 1998 for treatment and disposal of approximately 148 million gallons per year of leach pad solutions. As operated, it was undersized and hydraulic overloading occurred. Expansion of the land application area from 96 to 364 acres took place in the summer of 2000 and a comprehensive water management plan was developed to maximize the beneficial uptake of water and nutrients by the grass/hay crop. The high selenium and nitrate concentrations limit the assimilation capacity of the LAD, and a biological treatment system to remove these contaminants was tested. The pilot project was a success and a full scale pre-treatment plant began operating in 2002. High salinity and sodium accumulation on LAD soils and vegetation will be a limiting factor for application of solutions that will require monitoring.
- Impacts to the Madison Group aquifer from the Zortman and Landusky Mines are only expected to occur where mine-affected surface water and alluvial groundwater infiltrates near drainage bottoms where vertical gradients are downward, recharging the Madison aquifer.

### **3.4 SOIL and RECLAMATION MATERIALS**

Two major landforms and soil groupings are present in and around the mines. The first consists of the unglaciated mountain portion, characterized by steep, V-shaped valleys and gentler ridges. The second landform type is outwash plains and drainage bottoms, the Ruby and Goslin Flats areas.

The mountainous portion was not glaciated. Most soils developed in place from colluvium, but there are some alluvial soils in drainages. The degree of soil development is variable, from minimal development on talus slopes to well developed Mollisols (grassland soils) and Alfisols (forest and some grassland soils). Slopes greater than 50% are common.

#### **3.4.1 General Soil Description**

Appendix 3 to the 1992 Proposed Operating Permit is a Soil Survey of the Little Rocky Mountains Environmental Study Area, Phillips County, Montana (Noel and Houlton 1991). It includes a soils map and legend, description of soil series, profile summaries, and laboratory analysis of some chemical and physical parameters as they pertain to reclamation.

In salvaging soils and some subsoil material from disturbed areas for later use in reclamation, this material was stockpiled. In stockpiling, the developed upper horizons are mixed with substrates little modified by biological activity. The mix is different than the pre-disturbance soils described in the pre-mine soil inventory. Among these changes are the loss of distinct horizons with characteristic organic matter concentration, fertility, soil microbe populations, zones of calcium and clay loss and accumulation, base saturation, and coarse fragment content. Anaerobic conditions within stockpiles deplete soil microbe populations except for anaerobic bacteria. For reclamation, the properties of soil stockpiles have a far greater bearing than pre-mine inventories.

#### **Mountain Soils**

As part of a revegetation evaluation, Producers (2000) described four reference soils selected to characterize a range of mountainous soils with development beyond the Entisol level. The associated plant communities were bluebunch wheatgrass-balsamroot (soil: Loamy-skeletal, mixed, frigid, Typic Haplustoll), bluebunch wheatgrass with a scattered overstory of lodgepole and Ponderosa pine (soil: Fine-loamy, mixed, Ustic Argicryoll), well-developed soil with lodgepole pine overstory (soil: Loamy-skeletal over clayey, mixed, Ustic Haplocryalf), and doghair lodgepole (soil: Loamy-skeletal, mixed, Ustic Dystrocryept). Characteristics of these four soils are detailed in Tables 3.4.-1 through 3.4-3.

The grassland soils are more fertile than soils of coniferous forests (Table 3.4-1). Both grassland reference soils have rather high nitrate levels for early June at the height of the growing season. This indicates the continuous mineralization of nutrients from the organic fraction. Forest soils were less fertile but deeper. Conifers also can grow on fractured paralithic substrates, rooting in the fissures that conduct rainwater and

allow unrestricted root growth. Conifers can meet their nutritional needs by accessing a rather large volume of relatively infertile soil, whereas grasslands require more fertile soils but less rooting volume.

**Table 3.4-1. Fertility, Organic Matter Content, and pH of the Uppermost Mineral Horizon of Four Reference Soils near Mine Reclamation**

Vegetation Type	Nitrogen (ppm)	Ammonium (ppm)	Phosphorus (ppm)	Potassium (ppm)	Organic Matter (%)	pH (s.u.)
Wheatgrass-Balsamroot	5	72	36	740	17	6.2
Pine/Wheatgrass	6	15	61	240	3	7.0
Productive Lodgepole Pine	2.6	19	10	234	4	6.1
Doghair Lodgepole Pine	0.1	8	5	142	4	5.4

Physical properties of the four reference soils are described in Table 3.4-2. Coarse fragment content (the fraction of soil particles greater than 2 mm) is typically 50-70%. A well-developed soil that is accumulating soils fines, such as the soil of the bluebunch wheatgrass-balsamroot plant community, has fewer rock fragments in the A (upper mineral) horizon than below. A soil influenced by a lot of erosion (e.g. the soil of the pine/bluebunch wheatgrass plant community) loses soil fines (less than 2mm) at the surface, so it has more rock fragments near the surface than below. This is also true for much of the past mine reclamation.

**Table 3.4-2. Physical Properties of Reference Soils**

Vegetation Type	Soil Thickness (inches)	Surface Coarse Fragments (%)	Subsurface Coarse Fragments (%)	Surface Clay Content (%)	Surface Texture
Wheatgrass-Balsamroot	20	10/10	20/50	14	Cobbly loam
Pines/Wheatgrass	15	20/50	5/20	8	Gravelly loamy sand
Productive Lodgepole Pine	44	15	50	20	Channery loam
Doghair Lodgepole Pine	27	15/0	30/40	15	Gravelly sandy loam

The existing soil stockpiles comprise about 2 million loose cubic yards. Stockpiled and previously applied soil materials contain an average of 23% clay and 57% coarse fragments by volume. The texture is a little heavier (more clayey) than optimal for revegetation, but at the same time, more erosion-resistant than a less clayey soil would be. For maximum effectiveness, soil must not be compacted during placement. The tiny, unconnected pores of soils pose enough of a problem for plant roots, so compaction only exacerbates the problem. With good revegetation and microbial populations, soil structure would develop in time and improve growing conditions for vascular plants. The rock content is high and, in many respects, detracts from the exchange capacity and water-holding capacity of soils, but the high rock content inhibits erosion.

The most important consideration is that soil fines not erode away, leaving a rocky erosion pavement that is inhospitable to further plant establishment.

In addition to mixing, stockpiled soils undergo the depletion of microbe populations necessary for nutrient cycling. Soil fungi and with a few exceptions bacteria meet their energy and nutrient requirements by feeding on organic substrates, mostly plant matter. In healthy grasslands, the biomass of bacteria and fungi are roughly equal. Protozoa, the most primitive single-celled animals, feed on fungi and bacteria (and sometimes directly on organic matter). One important role of protozoa is transforming nutrients in fungi and bacteria. Nematodes, tiny unsegmented worms, can also be important in nutrient cycling, depending upon conditions.

The abundance of these microbes in reference soils is summarized in Table 3.4-3. The biomass of fungi is greater than that of bacteria in all reference soils, but greatest in the productive forest soil. Protozoa are rather poorly represented in these reference soils, particularly the forest soils.

**Table 3.4-3. Microbiological Properties of Reference Soils**

Plant Community	Bacteria (ug/g)	Fungi (ug/g)	Ratio Fungi/Bacteria	Protozoa	Nematodes
				Density	
Bluebunch Wheatgrass-Balsamroot	208	293	1.43	1,300	4.0
Pine/Bluebunch ref.	149	298	2.00	1,200	7.3
Wheatgrass (another date)	139	369	2.65	NA	NA
Productive Lodgepole Pine	137	555	4.05	40	4.7
Doghair Lodgepole Pine	151	340	2.25	110	6.4

### **Goslin Flats LAD-Area Soils**

The Goslin Flats LAD area was included in the Order 1 soil survey of the “Little Rocky Mountains Environmental Study Area, Phillips County, Montana” performed for the March 1993 *Application for Amendment to Operating Permit 00096*, submitted by ZMI to the State of Montana (Noel and Houlton 1991). The detailed soils map of Goslin Flats are presented in Exhibit 3-4 of that report. Most of the LAD area soils are Mollisols, with moderately to well developed profiles. The parent materials are alluvial terraces, colluvium and fans of poorly sorted gravel, shale, sandstone and limestone. Soil textures are dominantly gravelly loams, silty loams and clay loams on the surface, and silty clay loams, clay loams and clays in the subsoil. Coarse fragment contents increase in the northern end of the Ruby Creek valley. A summary of the soil types found in the Goslin Flats area is provided in Table 3.4-4.

Nearly the entire terrace constituting the original Goslin Flats LAD area is composed of Winspect cobbly loam soils, according to the soils map of Noel and Houlton. Detailed tabulations of soils classifications and laboratory test results may be found in the Noel and Houlton report contained in Appendix 3 of Volume 2, Application for Amendment to Operating Permit No. 00096.

**Table 3.4-4. Soil Types in the Goslin Flats LAD Area**

Soil Series Name	Dominant Texture	Major Soil in LAD Use
Judell	Clay loam	
Maiden	Gravelly loam	X
Martinsdale	Gravelly loam	
PAAB	Silty clay loam	
Pachel	Loam	
Riverside	Very gravelly loam	X
SAR	Silty clay loam	
SS	Loam	
Straw	Loam	
TAQ	Loam over very gravelly loam	
TU	Very gravelly loam	
UBB	Loam	
UBF	Loam over very gravelly loam	X
Vanda	Clay	Locally
VAQ	Gravelly loam over very gravelly sand	
Warhorse	Fine loam	
Williams	Loam	
Winham	Very gravelly loam	
Winspect	Cobbly loam	X

The Goslin Flats soil survey (Noel and Houlton 1991) was reviewed for potential limitations to expansion of the Goslin Flats LAD. The two identified potential limitations were slope (erosion concern) and certain soil textures (rapid permeability). The LAD expansion areas were selected to avoid unsuitable slopes. The predominant soil types on the terraces and alluvial valleys of the Goslin LAD area range from loam to very

gravelly loam. Loam and clay loam normally occur in the upper 6 to 12 inches, with increasing coarse fragments with depth. Coarse-textured subsoils with 35 to 60% coarse fragments are common.

These soil limitations were mitigated by making application rates commensurate with evapotranspiration demand, and the integration of soil lysimeter observations as a component of routine LAD management. If water is discovered in lysimeters, immediate reductions in water application occur in the affected area.

The predominant soil types and their water holding capacities are summarized in HSI and Spectrum (2000). The information indicates that the average weighted water holding capacity of the Goslin Flats LAD area soils is 4.55 inches in the upper 36 inches of soil profile. If 50% of this is assumed to be “depletable” for the purposes of irrigation demand, then about 2.25 inches of available water storage capacity is available for irrigation replenishment. At a typical summer evapotranspiration rate of 0.25 inches per day, this represents about 9 days of accumulated depletion, a reasonable irrigation schedule. Soil infiltration rates range from 1.3 to 2.7 inches per hour, and do not limit irrigation for sprinkler systems.

Additional sampling of soils in the Goslin Flats LAD area was conducted in March and May 2000 using backhoe test pits. Four locations distributed across the original LAD area were sampled. The samples were collected prior to pad water application, with a total of 19 samples collected from test pits, composited by subarea, by soil horizons. The objectives of the sampling were to prepare or confirm textural descriptions of the soil profiles and collect samples for chemical analysis. The test pit locations, details of methods, and results are provided in the report, “Goslin Flats Land Application Disposal Expansion Assessment and 2000-2001 Plan of Operations” (HSI and Spectrum 2000).

Table 3.4-5 presents trends in soil salinity parameters at the original Goslin Flats LAD area before and after the 1999 application season, and in early 2000. The data confirm that soil salinity and sodicity have increased to levels suitable only for salt tolerant plants. Fortunately, western wheat grass, the primary grass in the original LAD area, is salt tolerant. Soil salinity and sodicity are at levels requiring special management on the original LAD. Water application rates per unit area were significantly reduced in 2000 as the expansion areas were brought on line.

The 2000 soils analyses include acetic acid-extractable metals and trace elements from the original LAD area and expansion areas. All concentrations were below the suggested threshold levels, except aluminum. As discussed in HSI and Spectrum (2000), the laboratory analytical procedure detects colloidal aluminum, which is not considered bio-available. Based on previous experience, aluminum is not actually available to plants at these levels.

The soils within the Goslin Flats LAD area are generally considered suitable for land application of mine waters. The principal limitations are the high percentage of coarse fragments and rapid permeability of the subsoils. This limitation has been addressed in development of a comprehensive management plan as described in the Goslin Flats LAD Expansion Assessment report (HSI and Spectrum 2000).

**Table 3.4-5. Soil Salinity and Sodium Hazard Calculations at Goslin Flats LAD**

Date	Location	Depth (inches)	pH (s.u.)	EC mmhos/cm	SAR (%)	Calculated ESP (%)	Soil Condition (see key)
03/10/99	LS1A	4-12	6.02	1.653	11.1	13.13	4
03/10/99	LS1A	13-24	6.04	1.678	2.9	2.93	4
12/14/99	LS1A	0-6	6.3	11	19.8	21.84	2
12/14/99	LS1A	6-24	6.9	9.29	20.7	22.64	2
03/23/00	LS1A	0-6	6	7.67	17	19.23	2
03/23/00	LS1A	6-18	6.7	7.13	15.2	17.46	2
03/10/99	LS2A	5-12	6.07	2.77	16.11	18.37	3
03/10/99	LS2A	13-24	6.56	3.08	17.93	20.12	3
03/23/00	LS2A	0-6	6.7	7.01	16.1	18.36	2
03/23/00	LS2A	6-24	7.5	8.15	19.5	21.57	2
03/10/99	LS3A	5-12	5.97	1.544	3.36	3.56	4
03/10/99	LS3A	13-24	6.37	1.255	1.15	0.43	4
12/14/99	LS3A	0-6	6.1	2.95	5.08	5.87	4
12/14/99	LS3A	6-24	7.1	2.54	1.68	1.20	4
03/23/00	LS3A	0-6	6.5	6.82	16	18.26	2
03/23/00	LS3A	6-24	7.5	7.02	15.1	17.36	2
03/23/00	E2	0-6	6.1	6.57	16.1	18.36	2
03/23/00	E2	6-24	7.7	7.33	17.9	20.09	2

Notes: EC = Electrical Conductivity  
SAR = Sodium Adsorption Ratio  
Calc. ESP = Calculated Exchangeable Sodium Percentage  
Location E2 is near monitoring well ZL-211.

Key to Soil Salinity and Sodicity Levels:

<u>Soil Condition</u>	<u>Soil Classification</u>	<u>Plant and Soil Response</u>
1. EC>4 ESP<15	Saline-Nonsodic	Osmotic stress; well aggregated
2. EC>4 ESP>15	Saline-Sodic	Osmotic stress; potential dispersion
3. EC<4 ESP>15	Nonsaline-Sodic	No osmotic stress; dispersed
4. EC<4 ESP<15	Nonsaline-Nonsodic	No osmotic stress; well aggregated

Source: American Petroleum Institute, 1997; Remediation of Salt-Affected Soils at Oil & Gas Production Facilities

### 3.4.2 Soil Reclamation Potential

In addition to the reference soils discussed in the preceding section, Producers (2000) characterized soil stockpiles and soils that have been vegetated for five to ten years. Comparing reference soils to placed soils formed the basis for many aspects of the revised revegetation plan. Producers found that the soils were not

inherently limiting to reclamation, but that the soils' suitability or need for amendment/special practices varied among plant growth forms. For grasses and some forbs, the chief limitation is soil infertility. For other forbs, such as Cicer milkvetch, there is no limiting factor. For pine trees, the chief limitations are soil compaction and soil thickness.

A coarse fragment content of 50% or more is a limitation because rock fragments limit root penetration and hold virtually no water or exchangeable nutrients. Reference soils, however, have similar coarse fragment contents, so soils are suitable in physical respects although there is a limitation. Soils can be satisfactory growth media for grasses (with fertilization or nitrogen fixation) and forbs. For conifers, soils can be satisfactory growth media as long as they are uncompacted and adequately deep. The rooting depth can include non-acid generating substrates below the soil proper. A fungal dominance among soil microbes would promote healthy trees.

### **Soil Suitability and Availability**

In evaluating suitability, the physical, chemical, and microbiological properties of soils are important. The general physical and chemical properties of the Montana Gulch and Mill Gulch soil stockpiles, which together comprise 77% of the stockpiled soil, are:

Organic Matter 0.8%	Clay Content (in the fine earth fraction) 23%
Nitrate Concentration 1.5 ppm	Coarse Fragment Content by Volume (by visual inspection) 57%
Ammonium Concentration 4 ppm	Plant-Available Phosphorus 14 ppm
Plant-Available Potassium 170 ppm	pH 6.8 s.u.

### **Soil Stockpile Suitability**

The high coarse fragment content of the soils (Table 3.4-6) is a limitation in some respects, but it also has positive effects. For example, coarse fragments decrease the erosiveness of placed soils. However, if the soil fines are eroded away, the development of a rocky surface inhibits the establishment of arriving seeds.

Apart from the coarse fragment content, the texture of soil, ranging from sandy loam to sandy clay loam, is nearly optimal. One qualifier is that care must be taken not to compact soils which contain about 20% or more clay. Conifers would do best on the lighter (sandier) soils, whereas grasses and especially some forbs are well adapted to the heavier (more clayey) soils.

**Table 3.4-6. Particle Size and Texture of Two Soil Stockpiles**

Soil Stockpile Location	Coarse Fragment Content (%)	Sand Content (%)	Silt Content (%)	Clay Content (%)	Texture
Montana Gulch	65	NA	NA	24	Very gravelly sandy clay loam
Mill Gulch	65	NA	NA	24	Very gravelly sandy clay loam
Mill Gulch (top)	35	54	29	17	Very gravelly sandy loam
Mill Gulch (bottom)	42	50	34	16	Extremely gravelly loam

Soil fertility and organic matter content are summarized in Table 3.4-7. The nitrate levels seem good, but would quickly be immobilized by establishing revegetation. In soils, at least near the surface, the microbial mineralization of nitrogen and lack of vascular plants together result in concentrations of a few parts per million. Phosphorus and potassium are adequate, but higher levels would be optimal for revegetation. Summing up, fertilization with nitrogen and, to a lesser degree, phosphorus and potassium would make fertility optimal for grasses and forbs. Except for nitrogen, the stockpiled soil fertility is adequate for pine trees.

**Table 3.4-7. Soil Stockpile Fertility and Organic Matter Content**

Soil Stockpile	Nitrogen (ppm)	Phosphorus (ppm)	Potassium (ppm)	Organic Matter Content (%)
Mill Gulch (April)	5	14	190	1.0
Mill Gulch (June)	2	15	160	1.0
Montana Gulch (April)	1	14	160	1.0
Montana Gulch (April)	0.3	8	204	0.7
Average	2	13	180	0.8

When compared to reference soils (Table 3.4-3), microbiological data for the soil stockpiles shown in Table 3.4-8 reveal a deficiency of fungi. Five- to ten-year-old vegetated soils also exhibited this tendency. Protozoa are actually more abundant than in reference soils, and nematode density is similar to that of vegetated soils, although less than reference soils.

**Table 3.4-8. Microbiological Properties of Two Soil Stockpiles**

Plant Community	Bacteria (ug/g)	Fungi (ug/g)	Ratio Fungi/ Bacteria	Protozoa	Nematodes
				Density	
Mill Gulch Stockpile (June)	141	38	0.27	30,000	0.1
Montana Gulch Stockpile (June)	131	55	0.42	6,200	0.8

### **Soil Availability**

The four existing soil stockpiles at the Landusky Mine comprise about 2.67 million tons or 1.78 million loose cubic yards. At an assumed bulk density of 1.8 g/cc for placed soil (a no-compaction scenario), this volume could cover 730 acres to a depth of 18 inches. An additional 0.3 million tons of soil is stockpiled at the Zortman Mine.

In addition, about 75,000 cubic yards of King Creek alluvium/tailings is to be placed on the L80-82, L83, and L84 leach pads, providing about 6 inches of cover material. Four out of five King Creek samples were sandy (droughty, low cation exchange capacity), and the remaining sample was silty, which is better for growing plants but erosive (Table 3.4-9). King Creek material could augment the soil resource if mixed with soil or placed between soil and underlying substrate. For pine tree vegetation only, it could be placed on the surface of rocky substrates.

**Table 3.4-9. Two Methods of Textural Analysis of the King Creek Alluvium/Tailings**

Sample	Gravel Content (%)	Sand Content (%)	Silt Content (%)	Clay Content (%)	Silt+Clay* Content (%) and Texture
KC-01	28	68	2	2	4
Fine earth fraction	--	94	3	3	Sand
KC-02	27	69	2	2	4
Fine earth fraction	--	94	3	3	Sand
KC-03	27	60	7	6	13
Fine earth fraction	--	82	10	8	Sandy loam - loamy sand
KC-04	26	40	32	2	34
Fine earth fraction	--	54	43	3	Sandy loam
KC-05	24	61	9	6	15
Fine earth fraction	--	80	12	8	Sandy loam

\* Something like 15% (silt + clay) in the total volume – not just the fine earth fraction – is a reasonable value to identify minimally acceptable plant growth media. If the material is mixed with soils that have around 20% clay content, even coarse material can be beneficial.

Ruby Gulch alluvium may be used to augment the soil resource at the Zortman Mine. This material is gravelly (Table 3.4-10). The fine earth fraction is better suited to plant growth than King Creek tailings, but due to the “extremely gravelly” character, it also would function better mixed with soil or placed between soil and the underlying substrate.

**Table 3.4-10. Two Methods of Texture Analysis of the Ruby Gulch Tailings (Prodgers 2000)**

Sample	Gravel Content (%)	Sand Content (%)	Silt Content (%)	Clay Content (%)	Silt+Clay Content (%) and Texture
Z1	63	16	19	2	21
Fine earth fraction	--	43	51	5	Silt loam
Z2	60	20	17	3	20
Fine earth fraction	--	50	43	8	Loam
Z3	50	31	15	4	19
Fine earth fraction	--	62	30	8	Sandy loam

\* Something like 15% (silt + clay) in the total volume – not just the fine earth fraction – is a reasonable value to identify minimally acceptable plant growth media. If the material is mixed with soils that have around 20% clay content, even coarse material can be beneficial.

### 3.5 VEGETATION

The study area includes mountainous portions of the Little Rocky Mountains and the prairie plant communities of the Goslin and Ruby Flats areas. Mining activities have removed some vegetation, and some disturbed areas have been revegetated.

#### 3.5.1 General Vegetation Patterns

Culwell et al. (1990), in Appendix 4 of the 1992 Operating Permit Application, identified 25 types of plant communities in the study area (FEIS Table 3.4-1). Most of this diversity is attributable to riparian and lowland plant communities, whereas the upland forest zone has fewer types. Their vegetation map indicates the distribution patterns on a topographic base map. This diversity of communities is attributable to the variety of substrates, range in elevation, topographic features, hydrologic regimes, and land use histories. These communities can be grouped into seven vegetation types:

<u>Vegetation Type</u>	<u>Pre-Mine Acreage</u>
Grasslands	2,700
Shrublands	800
Lodgepole Pine Forest	7,300
Ponderosa Pine Forest	300
Douglas Fir Forest	300
Deciduous Forest	1,300
Rock/Scree/Disturbed	<u>1,700</u>
Total Pre-Mine Acreage	14,400

When mining ceased, a total of 851 acres at the Landusky Mine and 404 acres at the Zortman Mine had been disturbed. Since then, about 248 acres of mining disturbance have been revegetated at the Landusky Mine and 104 acres at the Zortman Mine, with another 21 acres of ancillary revegetation (clay pits, etc.). This acreage was seeded primarily to grasses and forbs to promote revegetation. In portions of the same acreage, 62,282 conifers (lodgepole and Ponderosa pine and Douglas Fir) and 21,918 shrubs were transplanted.

Culwell et al. (1990) provide a wealth of descriptive information for pre-mine vegetation, including a vegetation map, canopy coverage/species composition, productivity, tree and shrub densities, and species list. For forest types, data also was compiled for tree diameters, height, age, site index, and yield capability for each type.

Mine revegetation was monitored by various investigators. In general, the revegetation progress has been increasing plant cover for a few years, followed by subsequent shift in species composition and decline

in plant abundance. Producers (2000) sampled canopy coverage and computed species composition for most revegetated areas. The revegetation condition is summarized by the following weighted averages (weighted by acreage). The last three parameters are measures of plant diversity.

37.5%	Vascular Plant Canopy Coverage (Daubenmire 1959)
12 species	Species Richness (per 20½ m <sup>2</sup> plots)
5.4 species	Species with less than 1% Canopy Coverage (based on 20½ m <sup>2</sup> plots)
1.46	Equitability (Shannon In)

## **Forestry**

Most of the area in the mountainous landform was (and remains) lodgepole pine forest, with smaller areas of Douglas fir, Ponderosa pine, and mountain grasslands. Potential for commercial forestry is limited by tree size (mostly saplings and post-and-pole size timber) and distance to a processing facility. Minimally developed forest soils seem capable only of producing dense stands of small trees. Commercial use of these “doghair” stands is not feasible.

## **Riparian Areas, Wetlands, and Other Waters of the United States**

### **Riparian Vegetation**

Riparian vegetation was inventoried by Culwell et al. (1990). Examples of riparian plant communities are deciduous forest such as quaking aspen and paper birch, hawthorne thickets, and stands of chokecherry in coulees and on floodplains and grasslands. While some of these species can indicate the “hydrophytic vegetation” component of jurisdictional wetlands, wetland hydrology is often lacking in riparian areas, as are hydric soils.

### **Jurisdictional Wetlands**

The study area contains some swampy areas and a small amount of riverine wetlands. These are identified in the FEIS. In wetland accounting, the acreage of wetlands lost or gained is often accompanied by an assessment of wetland functions and values. While values are subjective and changeable, and functions are more often inferred than measured, the FEIS has five pages of tables documenting wetland functions and values.

## **Noxious Weeds**

Canada thistle and spotted knapweed were the two species on the noxious weed list for Phillips County which were observed in the study area when the 1996 FEIS was written. Producers (2000) did not observe any others, and in particular did not observe any noxious weeds in revegetated mined areas. The only

weed of note there, and it is not a noxious weed, is mullein (*Verbascum thapsus*). There is some localized cheatgrass (*Bromus tectorum*), and spotted knapweed is common in the community of Zortman. Even the attractive “sweet rocket” (*Hesperis matronalis*) in Zortman, no doubt a garden escapee, is considered a weed by some.

When weeds invade, it indicates that the arriving species can utilize resources that the existing plant community are not using efficiently, and that natural checks on the weed population are absent. For example, a weedy species may use soil moisture while other species remain dormant, or its rooting characteristics may allow use of resources at a different depth, etc. Poor grass revegetation, which characterizes much existing mine revegetation, is probably an open habitat to several species of arriving weeds. Dalmation toadflax, a forb of stoney slopes, is one prime candidate for the mountainous areas and rocky soils.

So far, weed control measures have been effective in the mine-affected portion of the Little Rockies. This success is attributable to both weed control measures and limited vehicular access. As public access increases, weed invasion of reclaimed areas is inevitable, but the degree of infestation and associated cost of control depend on many variables: which weeds are introduced, how well adapted they are, how promptly and effectively they are controlled, etc.

## **Plant Species of Special Concern**

### **Sensitive Species**

A specimen of a species of groundsel (a genus of the aster family), *Senecio eremophilus*, was collected near the head of Ruby Gulch in 1978 but has not been seen since. It retains its rating of S1 in Montana but this is a widely distributed species, ranging from British Columbia to Ontario and south to Arizona and New Mexico. Van Bruggen (1976) says of this species in South Dakota, “rare in wet soil along roadsides and in ravines in the black hills.” This sounds like an opportunist of narrow niche breath -- an impermanent species locally. Dorn (1992) mentions its occurrence in several portions of Wyoming.

An attractive species of figwort, *Penstemon grandiflorus*, has become common in some revegetated Zortman units that were reclaimed. It may have originated as a contaminant in a revegetation seed mix. This species is uncommon in Montana although previously collected. It has not been assigned a status by the Montana Natural Heritage Program but is being tracked. Large penstemon, as it is known, is common in portions of Wyoming and South Dakota.

### **Ethnobotany**

Ethnobotany refers to the study and use of plants by the different races of man. Species in the study area that have been used by local traditional cultures include chokecherry, juniper, snowberry, Oregon grape, bearberry, wild rose, and all tree species. One of the most avidly sought native species for ceremonies

and other uses, sweetgrass, has not been observed in the study area.

### **3.5.2 Metal Concentrations in Plant Tissues**

Application of leach pad waters to the Goslin Flats LAD began in 1998 and continued through 2000. Residual metals and other trace elements remain in the pad waters applied to the LAD. Some of these contaminants have the potential to accumulate in plant tissues, raising concerns about toxicity and palatability for livestock and wildlife.

Vegetation sampling was conducted in 1999 and 2000 to evaluate the levels of metals in LAD plants and to assess forage quality. Grass and forb samples were collected for bioassay analysis from the original Goslin Flats LAD. Samples were collected from the expansion areas prior to pad water application. Vegetation samples were collected in the fall of 1999 from a potential LAD site south of Landusky and at the Goslin Flats LAD area. The analyses test included aluminum, arsenic, boron, cadmium, copper, manganese, molybdenum, nickel, lead, selenium and zinc, calcium, sulfate, magnesium, sodium and chloride.

Comparison of the vegetation bioassay results between background sites and LAD areas leads to the following general observations:

- Values for the background samples at the Landusky LAD and Goslin Flats LAD expansion areas are generally consistent with “normal” ranges for unaffected vegetation, as presented by various authoritative sources (HSI and Spectrum 2000). Copper tends to be in the upper end of these ranges, with the grass sample from expansion area 7 (22 ppm) exceeding the normal range.
- Four elements were significantly elevated (above control values) in affected samples: copper, manganese, selenium and zinc. Copper increased from less than detection limits (5 ug/g) in control samples to 5-6 ug/g in affected samples. Manganese increased by a factor of about 7 from a range of 9-19 ug/g in control samples to 87-124 ug/g in affected samples. Selenium increased from less than detection limits (5 ug/g) in control samples to 6-15 ug/g in affected samples. Zinc increased by a factor of about 4 from a range of 7-13 ug/g in control samples to 31 - 40 ug/g in affected samples.
- Copper, manganese and zinc are generally within normal ranges, however, manganese and zinc are higher than mean values listed for grasses in Montana (HSI and Spectrum 2000). Selenium in affected samples exceeds the accepted normal ranges.
- Samples from the original Goslin Flats LAD were generally at the upper end of, or exceeded the “normal range” for cadmium, copper, manganese, zinc and selenium.
- Crude protein and total nitrogen averaged 57% higher in the original Goslin Flats LAD samples, compared to the background samples from the expansion areas.

- Sodium content was much greater, and iron somewhat lower in the original Goslin Flats LAD samples, compared to the background samples.
- Trace element levels in forbs generally equaled or exceeded that for grass in the same sample area.
- Bio-concentration of selenium by native grasses on the original Goslin Flats LAD have resulted in levels reaching 5 to 8 ppm, based on samples of grass and forbs collected in June 2000. The commonly recommended selenium guidelines for livestock consumption range from 2 to 5 ppm (HSI and Spectrum 2000). Some wildlife and aquatic organisms are known to be more sensitive to selenium uptake than livestock.

The US Forest Service and BLM in Idaho have issued interim guidelines for grazing on public lands affected by selenium, based on data collected at phosphate mines in Idaho, as follows:

- 50% of the vegetation sampled from a site must have selenium concentrations less than 5 mg/kg (ppm) selenium, dry weight;
- 45% of the vegetation sampled may contain concentrations of selenium between 5 mg/kg and 10 mg/kg dry weight; and
- No more than 5% of vegetation sampled may exceed 10 mg/kg dry weight, and no more than 0.5% of samples may exceed 20 mg/kg selenium dry weight.

Based on this guidance, the levels of selenium in vegetation on the Goslin Flats LAD area found in 2000 are at the lower level of concern for cattle grazing. The results for the expansion areas would pass the interim guidelines for Federal lands in Idaho. Samples from the original LAD would meet the third criteria, but not the first two. Most of the samples (6 of 8) exceeded 5 ppm selenium as dry weight, but the average of those samples greater than 5 ppm was 6.6 ppm, slightly over the 5 ppm criteria. Since the source of the selenium is application through sprinkler irrigation, the levels found in the LAD soils are more uniform than those found in the reclaimed phosphate mines in Idaho. This should make evaluation of toxicity risks somewhat easier for the LAD.

The LAD areas are fenced and unauthorized use by livestock is precluded. The Square Butte Grazing Association maintains grazing rights in the area. An grazing operator began grazing a small herd of steers on the original LAD area in September 2000. No ill effects had been observed by December 2000.

Copper and cadmium have bio-accumulated in the vegetation of the original LAD area, but are at levels generally below those adverse to livestock. Copper was present at an average concentration of 18.3 ppm in grasses and forbs, and cadmium averaged 0.85 ppm dry weight. These levels are at the upper end of the “normal” ranges (HSI and Spectrum 2000). Compared to background levels, copper was enriched by only a factor of 1.3, while cadmium was enriched by a factor of 3 to 4.

### **3.6 WILDLIFE and AQUATICS**

#### **3.6.1 Wildlife Resources**

The Little Rocky Mountains provide important mountainous habitat for mule deer and white-tailed deer, elk and bighorn sheep. Mule deer are common throughout the mountains from spring through fall. During winter months, mule deer are confined to southern exposures at lower elevations. White-tailed deer are also found year long in the mountains. Deciduous-shrub vegetation found in major creek bottoms, including Camp Creek, Alder Gulch, Beaver Creek and Lodgepole Creek, provide excellent cover as well as forage for white-tail deer. The Little Rocky Mountains provide moderate to high value habitat for elk. Herd size is limited due to the small size of the mountain range and hunting pressure. Current use of the area by elk results from dispersal from the Missouri River Breaks area to the south. Bighorn sheep are also found in the area. Saddle Butte, Silver Peak and Sugar Loaf Butte along the southern edge of the Little Rockies make up the primary winter range for bighorn sheep. The sheep use a wider range of the Little Rockies at other times of the year and have been sighted within the Zortman and Landusky Mine areas. Pronghorn antelope use the prairies that surround the Little Rocky Mountains but do not use the mountainous areas.

Black bears are occasionally sighted in the Little Rocky Mountains. Dispersion from the nearby Missouri River Breaks probably accounts for these observations. Coyotes and mountain lions are the two most common predators in the Little Rocky Mountains. Bobcats are sighted occasionally. Gray wolves are not known to occur in the area.

Blue grouse and a small population of wild turkeys can be found in the Little Rocky Mountains. Sage grouse, sharp-tailed grouse, grey partridge and ring-necked pheasant can be found in the foothills surrounding the planning area.

Golden eagles, red-tailed, ferruginous, and rough-legged hawks, American kestrel and great-horned owls are common through out the area at various times of the year. Cooper's hawk, northern goshawk and prairie falcon are occasionally observed.

At least seven species of bats use the area. Azure cave is one of several bat hibernaculums in the Pacific Northwest, and may be the northernmost hibernaculum in the United States. Current surveys of hibernating bats estimate the cave's population to be between 1100 and 1300 bats.

Numerous small mammal species and a few reptile and amphibian species may be found in the Little Rocky Mountains. None of them are considered to be a special status species.

Historical and potential habitat for seven species of wildlife, which are federally classified as threatened or endangered, occur within Phillips County. These species are bald eagle, peregrine falcon, black-footed ferret, least tern, piping plover, whooping crane and the gray wolf. In addition to these

species, the mountain plover and the black-tailed prairie dog are candidate species for classification as threatened or endangered.

Bald eagles have been recorded within the Little Rocky Mountains on one occasion during the Audubon Society Christmas Bird Count. However, there are no known bald eagle nests or essential habitat in the Little Rocky Mountains, and open water bodies that could provide nesting or foraging habitat do not exist.

There have been no reported sightings of gray wolves within the Little Rocky Mountains, which do not contain habitat suitable for maintaining a permanent wolf pack. There is no suitable habitat in the Little Rocky Mountains for the black-footed ferret, black-tailed prairie dog, least tern, piping plover, mountain plover and whooping crane.

The peregrine falcon is the only one of these species which has potential to be affected by the project. The high walls of the mine pits may provide artificial nesting habitat for the peregrine falcon. Higher quality nesting habitat is available for peregrine falcons in undisturbed areas within the Little Rocky Mountains, but to date there are no known peregrine falcons that nest within the mountains. It is doubtful that any nesting habitat at the mine site would be destroyed by reclamation activities.

Townsend's big-eared bat, a BLM species of special concern, are an insectivorous bat species that is known to occur in the Little Rocky Mountains. This bat may travel 6-8 kilometers from its roost site for foraging. Townsend's big-eared bat require water after roosting all day. Calm water bodies such as livestock ponds should be protected near roosting sites. Townsend's big-eared bat prefers to use caves around evergreen forests but is known to use abandoned mines for roosting. Azure Cave provides high value habitat for both maternity and hibernacula. (Rauscher 2000).

More detailed accounts of wildlife species present in the project area can be found in Section 3.5.1 of the 1996 FEIS.

### **3.6.2 Aquatic Resources**

Fisheries habitat in the Little Rocky Mountains is limited, due to the fact that most drainages are intermittent. Beaver Creek and Lodgepole Creek support a limited brook trout population. Both brook trout and rainbow trout have been recorded in Little Peoples Creek. In 1990 and 1991, ten streams were sampled for macroinvertebrates: Beaver Creek, upper Lodgepole Creek, lower Lodgepole Creek, Alder Gulch, Mill Gulch, Rock Creek, Montana Gulch, Bull Gulch, Big Horn Creek, and King Creek. On July 6, 1995, the BLM sampled Alder Gulch and Montana Gulch for macroinvertebrates. The findings on these two streams were similar to the 1990-1991 sampling. The dominant taxa were fly larvae (Chironomidae and Simuliidae), mayflies, stoneflies and flatworms.

The overall low total macroinvertebrate numbers, low diversity of taxa, and abundance of pollution-tolerant organisms reflect both natural changes and affects from previous mining activities (FEIS 1996).

A biological assessment of streams in the Little Rocky Mountains was conducted by Chadwick Ecological Consultants Inc. in 1996. Fourteen study sites were established on drainages surrounding the Zortman Mine site. Nine study sites were established on drainages surrounding the Landusky Mine site.

The fourteen study sites at the Zortman Mine were established as follows: Alder Gulch (4 sites), Alder Spur (1 site), Ruby Gulch (2 sites), Camp Creek (1 site), Lodge Pole Creek (2 sites), Beaver Creek (2 sites), Pony Gulch (1 site), and Carter Gulch (1 site). Of these fourteen sites, only nine had surface flows. The five sites which did not have surface flows are: The most downstream site on Alder Gulch, Alder Spur, Pony Gulch, and both sites on Ruby Gulch. At the nine sites with surface flows, physical habitat data was collected as well as a biological inventory. Of these nine sites, physical habitat data shows that these streams are relatively small, providing limited habitat. These streams had narrow channel widths, shallow water depths and low flows. The lower part of Alder Gulch, lower Beaver Creek and lower Lodgepole Creek had wider, deeper water channels with slightly higher flows. Only two sites had fish populations: the most downstream location on Beaver Creek, and the most downstream location on Lodgepole Creek. Brook trout (*Salvelinus fontinalis*) was the only species present at both locations.

Sixty-one brook trout were collected at Lodgepole Creek. These fish appeared to have recently completed spawning activity and were in below average condition. At Beaver Creek, 124 fish were collected at Beaver Creek. These fish were in full spawning readiness and average condition. Several size classes were present, indicating that this population was naturally reproducing.

Benthic macroinvertebrates were also collected at these nine sites. Numerically important invertebrate groups included stoneflies (Plecoptera), mayflies (Ephemeroptera), caddisflies (Trichoptera), and true flies (Diptera). Shannon-Weaver diversity values at all locations indicate healthy invertebrate communities (Chadwick 1996).

The nine sites associated with drainages at the Landusky Mine are as follows: Rock Creek (4 sites), Sullivan Park (1 site), Mill Gulch (1 site), Montana Gulch (1 site), King Creek (1 site), and South Big Horn Creek (1 site). Of these nine sites, eight had surface flows. The site with no flow was located on Rock Creek upstream from Montana Gulch but downstream of Mill Gulch. At the eight sites with surface flows, physical habitat data was collected as well as a biological inventory. Streams near the Landusky Mine were generally small with narrow, shallow channels and low flows. Montana Gulch and Rock Creek downstream of Montana Gulch had larger channels with somewhat higher flows. The most downstream site on Rock Creek was the only site where fish were present. Brook trout was the only species present. Two fish were collected, and both were in full spawning readiness and above average condition.

Benthic macroinvertebrates were also collected at these eight sites. Numerically important invertebrate groups included stoneflies, mayflies and true flies. Shannon-Weaver diversity values indicate balanced communities at most locations (Chadwick 1996).

### **3.7 AIR QUALITY and METEOROLOGY**

#### **3.7.1 Air Quality**

The FEIS reported that air resources at the mines are generally of good quality. No air quality data for the mines was available prior to 1990, and no data were collected prior to mining (FEIS, p. 3-178). Monitoring data concerning respirable particulates (PM<sub>10</sub>) were collected from March 1990 to April 1995 at up to 10 locations within the mine areas. The maximum 24-hour PM<sub>10</sub> concentrations in the area was 102 ug/m<sup>3</sup>. The Montana and Federal 24-hour ambient air quality standard for PM<sub>10</sub> is 150 ug/m<sup>3</sup>, and is not to be exceeded more than once per year. The annual Montana and Federal standard is 50 ug/m<sup>3</sup>. The background concentrations measured at the site are below the Montana and Federal ambient air standards.

There have been changes in the air emission point sources at the Zortman and Landusky Mines since the FEIS. The gold assay lab is no longer processing gold samples in Zortman, thereby eliminating a source of lead emissions. The refinery at the Zortman Mine process plant is not functioning. Hydrogen cyanide gas emissions from the heap leach pads may still occur, but most of the cyanide has decayed and such emissions are very small. When measured in 1990, hydrogen cyanide concentrations did not exceed 1 ppm. The Threshold Limit Value for hydrogen cyanide in air is 10 ppm (ACGIH 1991). Particulate and gaseous emissions from vehicle operations are still occurring on the mine sites, but to a lesser extent than during mining operations.

#### **3.7.2 Climate and Meteorology**

The FEIS described the climate of the Little Rocky Mountains as semi-arid and continental. Additional details regarding ambient temperatures, wind speed and direction were summarized in the FEIS (p. 3-184).

A number of meteorological monitoring stations lie in the vicinity of the Zortman and Landusky Mines. The NOAA weather station in the town of Zortman has been in operation since 1965. The BLM-Zortman station has operated since 1987 at the Zortman Mine. Other weather stations (Seven Mile Road, Gold Bug Butte, and Sullivan Park) were maintained by ZMI from 1990 to 1996 as part of an air monitoring program. The Zortman NOAA station and Gold Bug Butte station have been continuously operated from 1995 to the present, and provide the basis for the water balance presented in Section 3.3.

Other, more distant stations like Mocassin and Malta, Montana (operated by Montana State University) have been useful due to the lengthy or specialized records collected. The Mocassin station, located about 90 miles southwest of Zortman, has a long period of pan evaporation and other meteorological data useful for correlation to the mine sites. The Malta AGRIMET station was established in 1997 for farm irrigation scheduling by the U.S. Bureau of Reclamation in cooperation with Montana State University. It is a fully automated system with hourly satellite uplinks to a central processing station in Billings, Montana. Meteorological data and crop water use estimates may be accessed on a next-day basis via the internet. This

station was used in the Goslin Flats LAD area irrigation scheduling.

## **Precipitation**

The average annual precipitation at the Zortman townsite (1965-1995) was 18.7 inches. Of the years since 1995, 1996 was about average (-0.07 inches), 1997 and 1998 above average (+7.13 and +5.25 inches, respectively), 1999 below average (-2.32 inches), and 2000 below average (-2.31 inches). The Gold Bug Butte station was established in 1991, where the average annual precipitation through 1995 was 21.8 inches, compared to 19.93 inches for the Zortman NOAA station in the same period.

About half of the annual precipitation falls in the spring and early summer months (May-July) when intense thundershowers or snowstorms occur. The majority of total annual precipitation (~80%) occurs during the growing season (April-October).

The data indicate significant local variations in precipitation. The data suggest that the Landusky Mine receives on average more precipitation than the Zortman Mine. The various stations near the Zortman Mine also showed significant variations, both month-to-month and year-to-year. The Seven Mile Road station received significantly less precipitation than the other three stations near Zortman, which is likely due to the geographic location. Elevation does not appear to be the dominant factor, as the Zortman townsite and the Seven Mile Road stations are at similar elevation yet differed significantly in total annual precipitation. The climate data also indicate that through the early 1990s, wet and dry years alternated, with 1993 one of the wettest years on record (29.23 inches at the Zortman NOAA station). A succession of four years, 1995 through 1998, saw average to above average precipitation (25.83 inches in 1997), followed by relatively dry years in both 1999 (16.38 inches) and 2000 (16.39 inches).

## **Potential Evaporation**

Potential evaporation (pan evaporation) was measured by ZMI from 1991-1997. Pan evaporation rates ranged from 24.5 to 40.4 inches at the Gold Bug Butte station, to 28.0 to 49.5 inches at the Seven Mile Road station (WMCI, p. 170). The nearest weather station with similar climate conditions and a pan evaporation record is at Mocassin. Monthly pan evaporation rates for the period 1992 to 1997 were compared. The data indicate a generally good agreement of monthly evaporation rates for the years 1994-1996. However, in 1992 and 1993 the monthly pan evaporation rates at Mocassin were typically higher than at the Zortman Mine and, in particular, at the Landusky Mine. Pan evaporation is generally greater than that from a large open water body due to absorbed heat. Literature sources indicate that the expected lake evaporation rate for the Zortman Mine area is 38 to 43 inches per year.

## **Evapotranspiration**

Evapotranspiration is the actual amount of water removed by evaporation and transpiration from soils and

plants. It is smaller than the potential evaporation rate since it is often limited by lack of available moisture. Calculated mean annual evapotranspiration for the Zortman and Landusky Mines by the Thornthwaite equation is 19.4 and 21.0 inches, respectively. It is highly variable depending on temperatures, precipitation, ground cover, vegetation type and quality, and other factors.

The Malta AGRIMET station was used as the basis of real-time irrigation scheduling for the Goslin Flats LAD in 2000. The Bureau of Reclamation processes the hourly data and computes water use rates by various vegetation cover types on a daily, monthly and annual basis. The computed consumptive water use rates for pasture for the years 1998, 1999 and 2000 (April through September) was 24.8, 23.9 and 26.8 inches, respectively. The actual rates for pasture in the Zortman and Landusky areas are probably somewhat lower than at Malta. The evapotranspiration rates on the mine sites was estimated to be much lower than these values in the water balances (Spectrum 2000a and 2000b). This is due to cooler temperatures, thin or absent soil, and lack of vegetative cover over much of the mine sites.

3.8 LAND USE

The land use around the Little Rocky Mountains and near the mine sites is described in Section 3.7 of the 1996 FEIS, and in Chapter 3 and Appendix B. 2 of the environmental assessment prepared for the locatable mineral withdrawal application in the Little Rocky Mountains.

Public Land Order 7464(PLO), creating a locatable mineral withdrawal on a portion of the Little Rocky Mountains, was signed on September 18, 2000. PLO 7464 was published in the Federal Register on October 5 , 2000 (Volume 65, Number 194, Page 59463), which is the effective date of the withdrawal. The purpose of withdrawing 3,530.62 acres in the Little Rocky Mountains is to facilitate reclamation activities being conducted by the State of Montana and BLM at the bankrupt Zortman and Landusky Mines. The withdrawal is needed to secure the project area and sources of potential reclamation materials from mining claimants in order to complete reclamation as quickly and efficiently as possible, thereby preventing unnecessary or undue degradation. The withdrawal segregates Federal minerals in the Little Rocky Mountains from the location of mining claims for five years. The land remains open to mineral leasing and mineral material disposal.

There are 14 communication rights-of-way issued by the Bureau of Land Management on Antoine Butte, which is adjacent to the mining area. There are six communication buildings on Antoine Butte. The rights-of-way issued to Everett F. Tyrrel and TCI Microwave, Inc. are authorized to sublease to other communications users. Access to the Antoine Butte communication site is by verbal permission using the main access road between the mines. Communication buildings, BLM rights-of-way serial numbers, and the users are listed below.

Newer BLM Building

MTM-00590	Bureau of Land Management
MTM-08800	Bureau of Indian Affairs (Indian Health Service)
MTM-33660	Fish and Wildlife Service
MTM-38849	Phillips County
MTM-52008	Department of Health and Human Services
MTM-52860	Big Flat Electric Co-op., Inc.
MTM-58707	Montana Department of Justice
MTM-66582	Montana Department of Natural Resources and Conservation
MTM-88925	Montana Department of Transportation

Older BLM Building

MTM-08800	Bureau of Indian Affairs (BIA, Forestry Department)
MTM-45075	Hill County Electric Co-op., Inc.

Everett F. Tyrrel Building

MTM-35478

Everett F. Tyrrel

TCI Microwave Inc. Building

MTM-00998

TCI Microwave, Inc.

Phillips County TV Co-op. Building

MTM-01328

Phillips County TV Co-op.

United States Department of Justice Building

MTM-02340

United States Department of Justice (Border Patrol)

Forest resources in and around the Little Rocky Mountains consist mostly of ponderosa pine and Lodgepole pine. There are stands of Douglas-fir in and around the moister areas. Much of the area is overstocked with second growth ponderosa pine in the 3-8 inch diameter range with an overstory of 16+ inch mature ponderosa pine. Many of the natural meadows have an encroachment of ponderosa pine seedlings and saplings that are 25 years old or less.

In 1988 the Monument Peak Fire burned approximately 8,000 acres. Much of this area has regenerated naturally to Lodgepole pine. Walk-through surveys revealed as many as 10,000 seedlings per acre, ranging in size from a few inches to approximately two feet or less in height.

Past use of the forest resources include Christmas tree gathering, firewood use, sales of post and pole material and minor amounts of sawtimber.

There have been no grazing permits issued for the Little Rocky Mountains on or near the Zortman or Landusky Mines.

The Judith Valley Phillips Resource Management Plan EIS (BLM 1992) allows for the gathering of reasonable amounts of commonly available, renewable resources such as flowers, berries, nuts, seeds, cones and leaves for non-commercial use in accordance with BLM regulations at 43 CFR 8365.1-5. Commercial gathering or haying requires a contract or permit issued by a BLM-authorized official in accordance with 43 CFR 3610 or 5400.

## **3.9 RECREATION and VISUAL RESOURCES**

### **3.9.1 Recreation Resources**

A wide range of recreational opportunities exist in the area from picnicking, sightseeing and watching wildlife to hunting and fishing. These opportunities meet a diversity of visitor preferences. Participation in specific recreational activities varies according to the season of the year, with hunting and fishing dominating the fall scene and limited snowmobiling and cross-country skiing during the winter. Springtime activities include fishing, sightseeing and photography. Camping, picnicking, pleasure driving, sightseeing, fishing, hiking, collecting, and shooting prairie dogs dominate recreation during the summer months along with some dispersed off-road vehicle use. Overall, the area supports some type of recreational activity throughout the year, with the heaviest use occurring during the fall hunting seasons.

### **3.9.2 Visual Resources**

This section identifies and describes the visual resources of the study area, which includes those areas that viewers may travel through, recreate in, or reside in, or where existing views may be affected by the proposed action.

The description of the visual resources of the study area is based on the methodology described in the BLM's Visual Resource Inventory Manual. The visual inventory consists of three factors: (1) scenic quality evaluation, (2) sensitivity analysis, and (3) distance zone analysis. The scenic quality evaluation involves the rating of the scenic beauty of an area, which takes into consideration such factors as landform, vegetation, water, color, adjacent scenery, scarcity and cultural modifications. Sensitivity analysis is a measure of the public's concern for the scenic quality of an area, and is based on factors such as number of viewers, type of users (e.g. commuters or recreationists), public interest, and adjacent land use. Landscapes are also classified into distance zones based on visibility from travel routes or other possible sensitive viewing locations. Three distance zones are noted, including the foreground/middleground (0-5 miles), background (5-15 miles), and a seldom-seen zone (more than 15 miles or not seen).

Based on these three factors, lands are placed into one of four resource inventory classes. These Visual Resource Management (VRM) classes represent the relative value of the visual resource and provide a basis for considering visual values in the resource management planning process. Each VRM class has specific visual objectives defining how the visual environment is to be managed, with VRM Class I the most protective of the resource, and VRM Class IV allowing the most modification to the existing character of the landscape. The objective of each class is defined as follows (BLM 1986):

- Class I is intended to preserve the existing character of the landscape. This class provides for natural ecological changes; however, it does not preclude very limited management activity. The level of change to the characteristic landscape should be very low and must not attract attention.

- Class II is intended to retain the existing character of the landscape. The level of change to the characteristic landscape should be low. Management activities may be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture found in the predominant natural features of the characteristic landscape.
- Class III is intended to partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. Management activities may attract attention but should not dominate the view of the casual observer. Changes should repeat the basic elements found in the predominant natural features of the characteristic landscape.
- Class IV is intended to provide for management activities which require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high. These management activities may dominate the view and be the major focus of viewer attention. However, every attempt should be made to minimize the impact of these activities through careful location, minimal disturbance, and repeating the basic elements.

### **Baseline Visual Conditions**

The study area is in the Missouri Plateau section of the Great Plains physiographic province (Fenneman 1931). Located between the Missouri and Milk Rivers, the Little Rocky Mountains are an isolated group of domed mountains in an area roughly 10 miles in diameter. Their rounded crests rise nearly 3,000 feet above the surrounding plain, with steeply tilted hogbacks encircling the higher mountains. The topographic relief, colors, and textures of the mountains and their vegetation provide a contrast to the relatively homogenous terrain, lines, forms, colors and textures of the adjacent plains. In an assessment of the visual quality of the Little Rocky Mountains done by the BLM in 1979, the area was evaluated as Class A scenery, high sensitivity level, and distance zones ranging from foreground/middleground to seldom-seen views from several key observation points (KOPs) (BLM 1979). An analysis of these existing factors resulted in a VRM Class II visual determination for the BLM lands. The Judith Valley Phillips Resource Management Plan reaffirmed the VRM rating on these lands (BLM 1992). A separate visual study was conducted in 1995 for the draft EIS. Twenty-one different KOPs (visual points) were utilized in this analysis. Private lands affected by the proposed project are not included in the BLM visual resource designation.

The project study area includes a mountainous visual landscape. This area is highly visible to viewers on U.S. Highway 191, State Highway 66, and the county road (Seven Mile Road) leading to the town of Zortman, as well as from several of the surrounding buttes and peaks.

As the viewer travels into the project area in the foothills and mountains where the Zortman and Landusky Mines are located, the scenery changes from rolling grasslands to steep slopes and drainage bottoms. The landforms, colors and textures of the landscape have become more varied than the plains, and represent a

unique scenic resource within the High Plains province. Forms are more distinct, and range from sharply angular along ridges separating the many drainages, to the more rounded forms of the tops of the buttes. Coniferous vegetation provides year-round green color. The scattered open, grassy areas, rock outcroppings, and areas with dense tree cover provide variation in the overall textures and patterns of the landscape.

Current disturbances to the landscape include those activities associated with the Zortman and Landusky Mines. These visual contrasts include open pits, waste rock dumps, heap leach pads, plant facilities, and changes in vegetation pattern caused by logging and forest fires. Roads built for mine exploration and access, and for past BLM logging and fire-fighting activities, crisscross the surrounding slopes. Contrasts created by the existing facilities include color contrasts between the exposed soil and rocks and the surrounding vegetation, and contrasts caused by the alteration of topography. These contrasts, especially the surface disturbance at the Landusky Mine, are visible from many vantage points in the vicinity of the project area, as well as from more distant viewing locations, including areas along the Missouri River over 20 miles to the south, the CMR National Wildlife Refuge, and portions of the BLM Missouri Breaks Back Country Byway.

A simulation of the existing topography around the mining areas is shown in Figures E-1 and E-8 contained in Appendix E of the Draft SEIS.

### **3.10 CULTURAL RESOURCES**

The following excerpts from the 1996 FEIS are intended to provide a summary of the cultural resources in the project area. Refer to the FEIS, (p. 3-241, et seq.) for a more complete discussion.

#### **3.10.1 American Indian Cultural Resources**

Prior to the exploration and occupation of northern Montana by Euro-Americans, the Little Rocky Mountains were a place of particular importance to the Native Tribes of the Northern Plains. Due to topography, climate, and location, the Little Rocky Mountains provided a unique habitat for subsistence, social, and religious activities. In addition to the Gros Ventre and Assiniboiné, a number of other Plains tribes used the mountains for these same activities. Included were the Sioux, Chippewa-Cree, Blackfeet, and Crow.

Early travel accounts lack specific reference to the Little Rocky Mountains, or “Island Mountains” as they were known to the native inhabitants of the area, although visitors to the Fort Belknap area just after the turn of the century note the use of the area for religious activities. Both the Gros Ventre and Assiniboiné retain fasting, prayer, and the vision quest as primary individual rites. In particular, accounts of Gros Ventre ceremonies include the Feathered Pipe, Flat Pipe, and Sacrifice Lodge (Sundance). The most important group ceremonies for the Assiniboiné were the Sundance and the Horse Dance. Vision Questing is described as paraphernalia and plants used by the Gros Ventre and the Assiniboiné for ceremonial purposes. The diary and accounts of John Galen Carter, for example, detail the use of red, green, and yellow cloth, a cottonwood center pole, sweetgrass, willow branches, chokecherry bush, eagle feathers and body paints as some of the accessories of the Sundance celebration (Carter 1906-1907 cited in Deaver and Kooistra 1992).

Interviews with contemporary Gros Ventre and Assiniboiné conducted by Deaver and Kooistra (1992) and Strahn (1992, 1993) also document use of the Little Rocky Mountains during the 1800s and 1900s. Citing oral history interviews with Assiniboiné and Gros Ventre at Fort Belknap and literature sources, Strahn notes that small autonomous bands got together in the Little Rocky Mountains during the winter where food, water, and other necessary resources were readily available. During the summer, complex social activities were conducted here by a number of different tribes (Strahn 1993). In 1875, large numbers of Sioux held a grass dance on the eastern slopes of the Little Rocky Mountains and the Gros Ventre held their Old Man's Dance in approximately the same location four years later. This was also an important place for religious activities where supernatural knowledge and assistance was petitioned through prayers, offerings, fasting, and sacred dances. Annual Sundances were held here because they afforded the tribes a place to gather collectively and contained all the necessary natural resources to construct the lodge and undertake the ceremony. Strahn notes that “as a natural storehouse, marketplace, battleground and sacred shrine, the Little Rocky Mountains were, quite literally, a center of tribal being on the northwestern plains” (Strahn 1993).

The affected environment for the Little Rocky Mountains includes both its spiritual and physical characteristics, which are traditionally seen as inseparable. The Little Rocky Mountains are one of a set of island mountain ranges recognized as the lodges/homes of the spirits, which are inhabited by eagles (spirit messengers), and contain various peaks (spirit lodges) symbolizing tipis in an American Indian camp. The mountains are currently viewed as one of the last refuges where traditionalists can practice spiritual activities such as prayer, fasting, and making offerings. A portion of the Little Rocky Mountains is the main watershed for the Fort Belknap communities. Warm water springs are exploited for their healing powers and are often chosen as sweatlodge locations by the Gros Ventre and Assiniboiné. In addition, resource procurement was and continues to be an important activity in the Little Rocky Mountains.

Early ethnographers conducting research at Fort Belknap around the turn of the century also documented use of the Little Rocky Mountains for fasting and plant gathering. Kroeber (1908) describes Gros Ventre fasting in the hills and high places up on mountains to receive powers or become doctors and provides a list of 35 plants gathered for medicinal purposes. Lowie describes similar practices (Deaver and Kooistra 1992).

The Gros Ventre and Assiniboiné have historically and continue today to gather and use portable resources from the Little Rocky Mountains. Deaver and Kooistra (1992), Flemmer (1990,1991), McConnell (1990) and others have described and documented the past and present importance of resource procurement. Included are the use of trees, shrubs, plants, grasses, animals and animal products, fossil remains, and minerals for domestic, food, medicinal, and ceremonial purposes. Virgil McConnell testified at the public hearings for mine expansion held in Lodgepole on April 15, 1993, that there are over 100 plants gathered in the Little Rocky Mountains. Other Fort Belknap tribal members also testified to the importance of resource procurement in the Little Rocky Mountains. Deaver and Kooistra (1992) provide a list of 41 grass, plant, shrub, and tree resources, many of which have multiple uses. Thirty of these resources are used for medicinal purposes, 15 for ceremonial purposes, 5 have domestic uses, and 2 are used for food. Trees, which themselves are sacred, provide fuel and building material, and have been used historically for tipi poles (lodgepole pine), sweatlodges (willow), and Sundance lodges (cottonwood center pole). Sweet pine and juniper are used as well. The area is also used for hunting, fishing, and domestic animal grazing. Primary plants include sweetgrass, sages, larb, peppermint, prickly pear, rose roots, cherry bark, chokecherries, and certain fungi.

Culwell et al. (1990) include a section on ethnobotany in their study of vegetation resources conducted for the proposed mine expansion. They note that the Little Rocky Mountains have historically been and are currently a source of plant materials for ethnobotanical uses, that the mountains provide a variety of species associated only with isolated mountain or forest grassland ecotones like the Little Rocky Mountains, and that the relatively small size of the range situated within a prairie setting provides an extensive list of useful plants within a small geographical area. They identify 428 species of grasses, plants, forbs, shrubs, and trees within the Area of Potential Effect defined for vegetation resources for the project. They note that ethnobotanical use is documented for 200 of these species based upon research conducted in similar areas such as the Bears Paw Mountains, Cypress Hills, Sweetgrass Hills, Judith Mountains, Moccasin Mountains, and others. These

species can be expected to occur throughout the Little Rocky Mountain range. Ethnobotanical studies have not been conducted for the Little Rocky Mountains. Of the 41 vegetation resources identified by Deaver and Kooistra, however, 25 (64%) are included by the Culwell et al. study.

There has always been a preference for resources procured from the mountains since a great variety of species can be gathered in a fairly restricted geographical area and are considered more potent than their counterparts gathered from lower elevations. Flemmer (1991) notes that currently this preference includes the lack of dust along with agricultural chemical contamination prevalent at the lower altitudes. McConnell (1990) notes that Native Americans come from all over, including Canada, to gather plants in the Little Rocky Mountains. For the Fort Peck Assiniboine, the Little Rocky Mountains are the closest source of sweetgrass necessary for ritual purification smudging ceremonies. A wide variety of birds are reported in the area, including several types of hawks and golden eagles which are spiritually significant to both groups.

The Madison Limestones, which form a series of near vertical cliffs that encircle the Little Rocky Mountains, provide a material source for stone tool manufacture. The limestones form caves, many with Native American rock art, as well as crevasses, many of which contain burials respected and revered by the people of Fort Belknap. Fossils with traditional cultural uses include ammonites or “buffalo stones” and belemnites (used by prehistoric groups for ornaments and fetishes), as well as crinoid stars (used by modern Sundance leaders for rattles). A white clay substance (probably bentonite) is used by the Gros Ventre (known as the White Clay People) for staining their clothes and, today, to prepare hides. The Gros Ventre collect red and yellow paint pigments in the Little Rocky Mountains for use in a face painting rite. Rocks, especially granite, are also collected in the Little Rocky Mountains for use in the sweatlodge. Rocks are assigned spirits and are, in general, respected.

### **The Little Rocky Mountains as a Traditional Cultural Property District**

A joint position on National Register eligibility was developed by the Fort Belknap Community Council, the Bureau of Indian Affairs, and the Bureau of Land Management, which also entered into a Memorandum of Understanding in June 1994 to form a special task force to further study the potential of the Little Rocky Mountains as a Historic District. The eligibility position paraphrases Bulletin 38 (Parker and King 1990) in stating that the Little Rocky Mountains are eligible as a TCP because they are:

*a location associated with the traditional beliefs of Native American groups about its origins, culture history, and the nature of the world; are a location where Native American religious practitioners have historically gone, and are known to go today to perform ceremonial activities in accordance with traditional cultural rules of practice; and are a location where an identifiable community has carried out economic, artistic, and other cultural practices important in maintaining its historical identity.*

The BLM and the Montana State Historic Preservation Office have concurred that the district is eligible under criterion (a) of 36 CFR 60.4, “associated with events that have made a significant contribution to the

broad patterns of our history.” It was also recognized, however, that other sites and smaller districts within the Little Rocky Mountains District may be individually eligible under other criterion. The task force also recognized that the boundaries were “working boundaries” and could be amended at a later date dependent on additional information and consultation.

### **Traditional Cultural Practices**

Several scholars have reported the continued practice of traditional ways in the Little Rocky Mountains documenting sacrifice alone in the hills, fasting, and plant gathering (Cooper 1957), and, fasting in the hills during mourning, and experiencing visions of supernatural significance in the hills (Flannery 1953). Verne Ray disputes the notion of rapid acculturation and cultural disintegration, noting that the Gros Ventre have maintained a unique ethnic identity, different from Euro-American culture even though they have adopted material items of the Euro-American tradition (Ray 1975). Later researchers have focused on how the Indians have reacted and adjusted to change (Miller 1987) and the differing viewpoints of elderly Indians and younger Indians trying to learn and live in a traditional way (Fowler 1984,1987).

The literature published prior to 1988 lacks many specific statements about the sacredness of the Little Rocky Mountains and generally fails to identify specific vision quest locations. Deaver and Kooistra (1992) explain this apparent contradiction according to a combination of four factors: (1) vision questing is intensely personal and the experience and location are not to be discussed with others; (2) the religious practitioners and elders interviewed during the earlier studies withheld information from others not only because it was sacred, but because it was discouraged and at times illegal to engage in traditional religious rituals; (3) the Gros Ventre and Assiniboine believe that all places have spiritual qualities so that the identification of specific sacred places may be seen as nonsensical and arbitrary; and (4) researchers of the time were not particularly interested in particular localities.

In more recent times, many writers have noted a strong revival of interest in traditional cultural practices, including the sacrifice lodge (Sundance) and vision questing in the Little Rocky Mountains. Deaver and Kooistra (1992) surmise that this practice has become more common in the last 5-10 years; Flemmer (1990,1991) documents the practice and identifies some locations through interviews and field reconnaissance with tribal members; and Melton (1990,1993) provides similar kinds of information. Strahn (1992) also documents this resurgence of traditionalism, noting a relationship between this and environmental awareness and activism. Individual use of the Little Rocky Mountains for traditional practices was also apparent from the testimony of various tribal members during the public hearings for mine expansion held in Lodgepole on April 15-16, 1993 and in meetings and conversations with tribal members undertaken during that same time period (Woods 1993).

Mining in the Little Rocky Mountains can be characterized as heavy during the late 1800s through the turn of the century, cyclical from the 1920s through the 1940s and sporadic through 1951. The forest fire in 1936, subsequent loss of terrain to heavy rains in 1937, and a hiatus during World War II contributed to the absence of the intensive mining activities which characterized the earlier periods. After 1951, little serious

activity occurred in the Little Rocky Mountains until modern surface mining operations were initiated in 1979. (See FEIS Section 3.12.3.2)

The consequence of mining on vision questing and other traditional activities in the Little Rocky Mountains has been described in an Affidavit by Virgil McConnell, an Assiniboiné elder and religious leader:

*“Fasting Sites in the Little Rocky Mountains prior to the opening of the early mines in the 1800's consisted of many mountains: Gold Bug Butte, Mission Peak, Indian Peak, Silver Peak, Old Scraggy, Bear Mountain, Saddle Butte, Shell Butte (modern names). All of or most of these sites were lost by the mining operations of the 1800's. The start of heap mining in 1978 caused loss of McConnell Mountain, Damon Hill, McMeal Ridge, Monument Peak, all cliffs near the north side of the Little Rocky Mountains between Coming Day Butte and Whitehorse Canyon. At the present time, the people in the Hays area have only Eagle Child Peak and Otter Robe Ridge for fasting. Near Lodgepole, they only have cliffs between Brown Canyon and Kunnyhard Canyon, Coming Day Butte and Travois Butte. Expansion of the existing mines will threaten the remaining few sites. There is a resurgence of interest in traditional religion and the few remaining sites are even in more demand. Loss of fasting sites will take away the ability of local traditional people to practice their religion.” (McConnell 1990)*

The onset of the period of modern mining (1979 to 1994) saw a sharp increase in activities which compromised the use of the Little Rocky Mountains for traditional cultural practices at the same time that a revival of interest in such activities was taking place. McConnell notes that a number of sites were “lost” prior to 1979 and others “lost” after 1979 with the initiation of heap leach mining. Prior to 1979, significant physical disturbance had occurred in Montana Gulch, Beaver Creek and Pony Gulch, and mill tailings were deposited in King Creek, Alder Gulch, and Ruby Gulch. Visual and noise disturbance to these and adjacent areas was ongoing. All of these previously disturbed areas are at or near important ethnographic sites. Since 1979, there has been additional physical disturbance to these areas and extensive physical disturbance by mining near or on Antoine and Shell Buttes, and Gold Bug Butte and Mission Peak.

It is important to point out, however, that while some of these sites have been physically disturbed and altered, and others rendered less desirable because of the ongoing visual and noise disturbances, some are still in use, and some of those in use are within a mile of the Zortman and Landusky Mines. The best information available indicates that favored spiritual locations continue to be used by some individuals, even though they are in the vicinity of the mines. On Mission Peak, for example, there is evidence of recent vision questing on the west side of the peak, away from the mining activities to the east.

### **3.10.2 History**

Early recorded intrusions by non-Indians into the general area were by the Lewis and Clark expedition of 1805, although Lewis and Clark did not explore the Little Rocky Mountains. The archaeological and ethnographic records indicate that the general area had been occupied for thousands of years previously, and was occupied at the time of Euro-American exploration and use. Following exploration, early

Euro-American use of the Little Rocky Mountains in the first part of the 19th Century was by fur trappers, with prospectors following in the last decades of the century.

Beginning in the middle of the 19th Century, the U.S. Government initiated the first of several treaties with the Plains Indians, first to facilitate exploration and trading by delineating tribal territories and discouraging intertribal warfare, and later to open up former tribal lands to settlement for purposes of farming, ranching, and mining. The Fort Laramie Treaty of 1851 gathered all the Plains tribes together and “mapped out the domain of each tribe and obligated each tribe to respect the lands of its neighbors” (Malone and Roeder 1976). Stemming from the efforts of Isaac I. Stevens, the 1855 Treaty created a vast Indian Reserve in northern Montana which was shared by Gros Ventre and Assiniboiné with the Blackfeet. This Reserve included the Little Rocky Mountains.

In 1887, the Northwest Commissioners negotiated the formation of the Blackfeet, Fort Belknap, and Fort Peck Reservations. The reservation underwent one reduction in 1896 after gold was discovered in the Little Rocky Mountains. Under the Grinnell Agreement, the tribes ceded 14,758 acres of land (Act of June 10, 1896, 29 Stat. 321, 350) in the mountains at the southern end of the reservation for \$360,000 in annuities. There is still controversy among Fort Belknap as to the terms and extent of the agreement.

The first sustained Euro-American use of the Little Rocky Mountains was in 1884, when Pike Landusky and others developed the first paying placer mines in Alder Gulch, leading to the development of the town of Landusky. Landusky later staked the first patented lode claims in the Little Rocky Mountains (recorded in 1892), as the early placer workings had rapidly been depleted. The richest claim was the August, patented in 1893, on the Fort Belknap Indian Reservation.

Mine and mill development proceeded through the first two decades of the twentieth century. Zortman was established as a mining camp in 1903 with the construction of a cyanide mill in Alder Gulch. Other stamp and crusher mills were constructed (the Ruby Gulch Mill as one of the larger ones), processing ore from the Ruby and Independent Mines. Ore processing included the use of cyanide, which had been utilized in the Little Rocky Mountains since the 1890s. Zortman grew faster than Landusky or Whitcomb (abandoned in the 1940s), although growth was as sporadic as work in the mines. From the 1920s through 1942, mining could be characterized as cyclical. Ventures were formed with some development and production; however, production did not usually continue for more than a few years. The ore in the Little Rocky Mountains was not of consistently high quality to sustain most of the mines utilizing the mining techniques of the day. Additionally, sporadic fires impacted both towns and mining operations. Much of Zortman burned in 1929, and the 1936 fire burned over 23,000 acres of timber.

Mining continued sporadically through 1951, with a hiatus during World War II. After 1951, little serious activity occurred here until the modern, surface mining operation opened in 1979. It has been estimated that over 380,000 ounces of gold were mined from the Little Rocky Mountains prior to 1979, contributing significantly to the region's economy.

### **3.11 SOCIAL and ECONOMIC CONDITIONS**

#### **3.11.1 Social Conditions**

The study area for social conditions includes Phillips and Blaine Counties. The Zortman and Landusky Mines are located in southwestern Phillips County near the unincorporated towns of Zortman and Landusky. The border of Blaine County and the Fort Belknap Indian Reservation is located directly north of the mines.

The population of Phillips County was 4,601 in 2000, a decline of 11% from 1990. The county lost population due to out-migration in every 12 month period between 1990 and 1999, except between July 1994 and July 1995 when it gained population due to in-migration. The out-migration in the years 1995 to 1998 was associated with the closure of the Zortman and Landusky Mines. The population in Phillips County is projected to decline very slowly (less than 2%) in the next decade.

The population of Blaine County was 7,009 in 2000, an increase of 4% from 1990. The population increase was due to the high birth rate and relatively low level of out-migration. The 2000 population of the Fort Belknap Indian Reservation, which is mostly located in Blaine County, was 2,959, which represents an increase of 18% from 1990. Nearly one-half (47%) of the population in Blaine County is American Indian. The population of Blaine County is expected to continue to increase, although at a slower rate (less than 1% for the decade) than in the 1990s.

Indicators of social well-being for Phillips and Blaine Counties present a mixed picture suggesting the planning area possesses the positive and negative factors associated with rural areas (FEIS 1996). The percentage of persons in poverty (1997 estimates) shows the rates to be higher in both counties than for Montana as a whole. The poverty figures were 27% for Blaine County and 19% for Phillips County, compared to 16% for the state as a whole. The most recent year poverty information is available for the Fort Belknap Reservation is 1989. However, BIA Labor Force Surveys indicated in 1997 that 42% of the Fort Belknap Indian Community employed on the reservation earned below the poverty guidelines. In 1998, per capita personal income continued to be well below the state figure for both counties in the study area.

The social values and ability to adapt to change by residents of Phillips and Blaine Counties and by the Fort Belknap Indian Community are addressed in detail in the 1996 FEIS. A summary of this information follows.

Residents of Phillips County place considerable value upon self-reliance, small-town life, and the availability of natural resources. Self-reliance is typified by the provision of many essential public safety and health services through volunteerism. They value the positive attributes of rural, small-town life such as good, friendly people; uncrowded surroundings; good schools for children; access to outdoor recreation; lack of crime; and lack of urban congestion. In Phillips County, commercial mining and oil and gas production have

been part of the local economy since the early 1900s. Although Phillips County and Malta are considered progressive and have a good business climate, the economy is stagnant and young people often must leave because of the lack of job opportunities.

A concern to many people is the negative socioeconomic impact that mine closure has had on mine workers and the area's economic base. This had created interest in the economic opportunities that might arise from both reclamation and possible future mining. Specific concerns are the short-term employment opportunities associated with the reclamation earthwork, the longer-term employment opportunities for site care and maintenance, and hiring preferences. Another concern is that the reclamation not preclude the potential for future mining and its associated economic benefits.

Social values in Blaine County vary among the three largest social groups: farmers and ranchers, townspeople, and American Indians of the Fort Belknap Reservation. Blaine County farmers and ranchers are generally political conservatives whose predominant social values are frugality, self-reliance, and hard work. Independence and a close tie to the land are dominant elements of this group's lifestyle. The townspeople of Harlem and Chinook value the attributes of local, small-town life: informal, personal interaction with others; knowledge and awareness of the personal and socioeconomic characteristics of neighbors; a quiet, predictable pace of life; mutual support among families and friends; volunteerism in the provision of essential public safety and social services; and religious affiliation.

The social structure of Blaine County is an adaptive one which addresses local issues through cooperative action and provides mutual support in the face of change that is beyond local control. In Blaine county, one may feel empowered within the local web of civic, social, fraternal and religious organizations. These groups have cooperated with each other to address community issues of housing and neighborhood revitalization and economic development.

The Fort Belknap Indian Community, centered on the Fort Belknap Indian Reservation, includes two tribal groups, the Assiniboiné and Gros Ventre, which have distinct tribal histories, experience and concerns. As a group, the Assiniboiné characterize themselves as sticking together, getting along with one another, and looking for direction from the oldest, wisest, and most spiritual among them (tribal elders). American Indian religion and traditions are highly valued. As a group, the Gros Ventre characterize themselves as valuing occupational accomplishment, education attainment and, to an extent, economic well-being.

The social structure of the Fort Belknap Indian Community is complex. Although divided in many ways, the community shows increasing evidence of group action on local issues. Most group action to promote economic well-being and solve social problems involves agencies of the Fort Belknap Indian Community Council. Recent examples include a campaign to save the Indian Health Service hospital, and the promotion of hunting, fishing and tourism on the reservation.

Areas within the Little Rocky Mountains, and specific sites near the mines are culturally and historically important to various North American Indian Tribes. The existing mine disturbances have created impacts

that affect the use of the mountains for traditional cultural practices. The development of reclamation measures that would make the mountains more conducive to traditional cultural practices is an issue.

### **3.11.2 Economic Conditions**

The study area is situated within Phillips County and adjacent to Blaine County and the Fort Belknap Indian Reservation. The economy of the two-county area, including Fort Belknap, is described in the 1996 FEIS. The Judith Valley Phillips Resource Management Plan EIS (BLM 1992) also contains a description of the economy for a larger geographic area in north-northeast Montana, including the study area, and is not specific to the impacts of a mining proposal. The analysis of the economics of the area contained in those two EIS's is incorporated by reference into this environmental assessment, and is supplemented with more recent data.

Economics topics discussed in this section are employment, income, local economic effects of existing reclamation activities at the Zortman and Landusky Mines. The analysis focuses primarily on Phillips County, since most of the effects are felt in Phillips County. Blaine County is also included in the analysis of employment and income since a portion of the current reclamation workforce resides in Blaine County, some of which reside on the Fort Belknap Reservation.

As described in the 1996 FEIS, the economy of Phillips and Blaine Counties is primarily agricultural. Economic diversity began to increase following the opening of the Zortman and Landusky Mines in 1979. For Phillips County, average annual mining employment gradually increased over time, peaking in 1991 and again in 1994 at about 280 jobs. For the first half of the 1990s, mining employment contributed from 15% to 18% of total average annual employment. Since 1996, average annual employment in mining has steadily decreased as mining activities declined, comprising about 1% of total employment for 1999 (17 jobs of 1,319 total average annual employment for the county), the last year for which average annual employment data are available (Montana Dept. of Labor and Industry, various years (a)). Table 3.11-1 shows detailed 1999 average employment for Phillips County.

For Blaine County, average annual mining employment gradually increased over time as well, peaking in 1992 and 1993 at about 10 jobs. Even at its peak, mining contributed less than 1% of total average annual employment in Blaine County (10 jobs out of about 1,500 in the county in 1992 and 1993). As for Phillips County, Blaine County's mining employment has steadily decreased as mining declined, comprising 3 out of 1,480 jobs in 1999, less than one-half of 1% of all jobs in the county in 1999 (Montana Dept. of Labor and Industry, various years (a)). Table 3.11-1 shows detailed 1999 average employment for Blaine County. It should be noted that the section below describing current reclamation activities at the mines shows that mining-related employment in 2000 has increased once again.

Some of the current employment associated with reclamation activities are categorized as construction (more specifically, heavy construction). County data on average annual construction employment for Phillips County indicates that jobs held relatively steady throughout the 1990s, but then increased from

about 34 jobs in 1998 to 49 jobs in 1999. For Blaine County, average annual construction employment has also been relatively steady throughout the 1990s, although there was a one-year spike in 1996 when employment increased from 31 to 46, then decreased again to 36 jobs for 1997.

During peak mining in the early 1990s, the unemployment rate in Phillips County was among the lowest in the state, averaging 3.9% in 1993 and 3.2% in 1994, while the state average was 6.9% and 6.1%, respectively. However, since 1995 the unemployment rate in Phillips County has been above the state average. The 1999 unemployment rate in Phillips County of 7.6% is a full percentage point lower than the county's highest level of unemployment over the past 10 years (8.6% in 1998), but the county still ranks 10<sup>th</sup> highest out of 56 counties in unemployment. (Source: Montana Department of Labor and Industry, various years (b))

For Blaine County, the unemployment rate has been consistently higher than the state unemployment rate during the 1990s. The county's lowest unemployment level was 7.1% in 1994, and its highest was 10.2% in 1997. In 1999, Blaine County's unemployment rate was 8%. It ranked 7th highest in unemployment for the year, tied with Musselshell County. (ibid)

For the Fort Belknap Indian Reservation, detailed employment data by industry is not available after the 1990 Census. With respect to unemployment rates, there are two different sets of data, one compiled and reported by the Bureau of Indian Affairs (BIA) and one compiled and reported by the Bureau of Labor Statistics (BLS). The BIA's *Labor Force Survey* estimated the 1999 unemployment rate to be 76%. For 1999, the BIA Labor Force Survey estimated the total workforce to be 2,780. Total employed was estimated to be 658 and total unemployed was estimated to be 2,122. The unemployment rate of 76% was calculated as the ratio of 2,122 unemployed to 2,780 total workforce ( $2,122/2,780 = 76\%$ ).

The BLS estimated the 1999 unemployment rate to be 22.9%. BLS data show the civilian labor force (similar to BIA's 'total workforce') as 830 persons, total employed as 640, and total unemployed as 190. The BLS unemployment rate of 22.9% was calculated as the ratio of 190 unemployed to 830 civilian labor force ( $190/830 = 22.9\%$ ).

Both agencies report a similar number of *employed* persons for 1999: BIA estimated the number of employed as 658 and BLS estimated the number of employed as 640.

There are three major differences in how the two agencies' estimates are determined. *First*, with respect to geographic area, BIA counts tribal members within a 3-county area (Blaine, Hill, and Phillips Counties). BLS counts residents of the Fort Belknap Reservation only and without regard to tribal membership.

*Second*, the two agencies use different methodologies to estimate unemployment rates. Generally, BIA first estimates total tribal enrollment, then separates this estimate by age group (including the working-age group of 16-64 years of age), and then determines the number of people 16-64 years of age who are either

‘employed’ or ‘not available for work.’ Then the number of unemployed is determined by subtracting the ‘employed’ and ‘not available for work’ from the total working-age group 16-64 years of age.

The BLS, in order to estimate the number of unemployed persons, conducts a monthly household survey to determine how many people are not working but actively seeking employment. This information is used to estimate unemployment rates at the state, county, and reservation level. As a separate exercise, BLS estimates the number of employed persons through existing employment data. Finally, BLS adds the number of employed persons to the number of unemployed persons to determine what they officially call the ‘civilian labor force.’

*Third*, BIA counts people not actively seeking work but who are available for work (e.g. discouraged unemployed people no longer looking for work, full-time homemakers, etc.). BLS counts only unemployed who are actively seeking employment. BLS numbers do not include discouraged unemployed persons and those unemployed people not seeking employment (such as full-time homemakers).

In summary, BIA and BLS use different sets of data which result in significant differences in estimated unemployment rates for the Fort Belknap Indian Reservation.

Since the mines’ closure, the area economy has lost some diversity and the primary economic base is once again agriculture. Industries with the highest level of employment in Phillips County are: government (415 jobs, 31% of total employment, of which 335 are local government jobs and 82 are State or Federal jobs), services (310 jobs, 24%), and retail trade (228 jobs, 17%) (see Table 3.11-1). *Per capita* personal income in 1997, the latest year for which data were available, was estimated to be \$17,010, an 11% increase from 1997's peak of \$15,260. *Total* personal income for the county for 1998 was \$81.6 million, a 9-percent increase over 1997's over 1997's total personal income of \$75.1 million. Most of the increase in personal income in the county is due from improvements in farm income.

In Blaine County, like Phillips County, the industries with the highest level of employment are: government (662 jobs, 45% of total employment, of which 441 are local government jobs and 221 are State or Federal jobs), services (326 jobs, 22%), and retail trade (219 jobs, 15%) (see Table 3.11-1). *Per capita* personal income in 1998, the latest year for which data were available, was estimated to be \$15,360, a 12% increase over 1997's *per capita* income of \$13,760. *Total* personal income for the county for 1998 was \$108.9 million, an 11-percent increase over 1997's total income of \$98.3 million.

**Table 3.11-1. Average Annual Employment by Industry for Phillips and Blaine Counties - 1999**

Industry	Phillips County		Blaine County	
	Employment	% of Total Employment	Employment	% of Total Employment
Agriculture, Fisheries, and Forestry	37	3%	41	3%
Mining	17	1%	3	0%
Construction	49	4%	33	2%
Manufacturing	51	4%	21	1%
Transportation, Communication, and Public Utilities	70	5%	13	1%
Wholesale Trade	73	6%	99	7%
Retail Trade	228	17%	219	15%
Finance, Insurance, and Real Estate	55	4%	60	4%
Services	310	24%	326	22%
Government	415	31%	662	45%
Total	1,319	100%	1,480	100%

Source: Montana Department of Labor and Industry, Office of Research and Analysis (various years (a)).

### **Economic Effects of the Interim Reclamation**

There are currently about 30 employees working on interim reclamation activities at the Zortman and Landusky Mines. According to the contractor, about 90% of the current workforce is from the study area and about one-third is American Indian (Spectrum 2000d). Total expenditures for the year 2000 were \$5.0 million (Spectrum 2001a). Of that total, about one-third, or \$1.5 million, are estimated to be wages and operating expenditures in the two-county study area. Of that \$1.5 million, about \$1.2 million are estimated to be dollars actually spent in the local area, after deducting for taxes and benefits paid to workers and which are not available to be spent locally.

The \$1.2 million are direct local expenditures which create additional rounds of spending, known as the multiplier effect and which represent an additional economic benefit to the study area. Total economic activity associated with local expenditures is estimated through the use of the IMPLAN Input-Output Model, which calculates the multiplier effect to spending. In the study area for the year 2000, it is estimated that total employment would be about 62 jobs, including the number of workers at the mine sites. Sixty-two jobs represents about 2% of average annual employment in the study area (62 jobs of a total 2,799 in the two-county area). Total employee compensation would be about \$311,000. Total output

in the study area would be about \$1.5 million. Table 3.11-2 shows these impacts. It should be noted that because many of the additional jobs (32 of the 62 total estimated) generated through additional spending already exist (e.g. jobs in retail outlets), additional spending by wage earners and the contractor may not result in more hiring by local businesses.

**Table 3.11-2. Estimated Total Economic Impact to Study Area for Year 2000 Interim Reclamation (current \$)**

Mine	Final Demand	Total Industry Output	Value Added		Employment
			Employee Compensation	Total Value Added	
Zortman	\$622,300	\$729,400	\$155,400	\$329,200	31
Landusky	\$622,300	\$729,400	\$155,400	\$329,200	31
Total	\$1,244,600	\$1,458,800	\$310,800	\$658,400	62

Note: "Final Demand" includes wages paid to reclamation workers at the mine sites and direct expenditures by the contractor on goods and services in the local study area. Wages paid to workers were deducted by 25% to estimate "disposable income" to account for taxes, savings, and employee benefits that are not part of workers' local spending. "Employee Compensation" includes wages paid for jobs generated in the study area as a result of spending by the contractor and reclamation employees. Source: IMPLAN Input-Output Modelling System (1999)

### 3.12 RECLAMATION and BONDING STATUS

At the conclusion of the Pegasus Gold Corporation, Zortman Mining, Inc., bankruptcy proceedings in January 1999, there were seven surety bonds covering the Zortman and Landusky Mines totaling more than \$67 million. These bonds cover surface reclamation, water treatment, exploration-related disturbances, and construction borrow source reclamation. In addition to the surety bonds, the bankruptcy court awarded a lump sum settlement to the agencies of \$1,050,000. These bonds and settlements are listed in Table 3.12-1. Through December 2000, approximately \$16 million has been spent on reclamation-related. These expenditures are also shown on Table 3.12-1.

**Table 3.12-1. Reclamation Bond/Funds Summary**

<b>Bond/Fund</b>	<b>Beginning Balance</b>	<b>Expenditures through Year 2000</b>	<b>Remaining Balance</b>	<b>Percent Spent</b>	<b>Percent Remaining</b>
Zortman Mine Reclamation Surety Money	\$10,024,000	\$1,709,173	\$8,314,827	17.1%	82.9%
Landusky Mine Reclamation Surety Money	\$19,600,000	\$3,542,162	\$16,057,838	18.1%	81.9%
Consent Decree Construction Bond	\$10,100,000	\$7,271,150	\$2,828,850	72.0%	28.0%
Water Treatment Operation & Maintenance through Year 2017	\$14,626,422	\$2,925,284	\$11,701,138	20.0%	80.0%
Long-Term Water Treatment Trust Fund	\$12,300,000	\$0	\$12,300,000	0.0%	100.0%
Bankruptcy Settlement Funds	\$1,050,000	\$1,050,000	\$0	100.0%	0.0%
Exploration Bond Amount	\$380,000	\$0	\$380,000	0.0%	100.0%
Open Cut Bond Amount	\$295,000	\$0	\$295,000	0.0%	100.0%
Totals	\$67,700,422	\$16,497,769	\$51,202,653	24.4%	75.6%

Note: The long-term water treatment trust fund was funded with an initial \$3,794,000 through December 1999. The fund has a value of \$12.3 million at maturity in 2017. Exploration and Open Cut bond amounts are not included in totals.

Since assuming management control of the mine site, the principal reclamation activities have included: overall site management; collection and treatment of seepage and pumpback water; management and treatment of leach pad solutions; interim reclamation involving backfilling and regrading of mine pits and leach pads at both mines; and preparation of engineering investigations and reclamation plan developments.

### **3.12.1 Overall Site Management**

At the conclusion of the Chapter 11 bankruptcy proceedings, the agencies assumed control of the mines on January 15, 1999. Although mining ceased in 1998, the site continues to require active oversight and maintenance. Leach pads still contain solution that does not meet water quality standards for discharge, seepage capture systems need to be monitored and maintained, and site maintenance is required to avoid environmental degradation from such things as surface water runoff. In order to ensure ongoing care and maintenance of the site, the services of a third party contractor were retained to manage the site. Their duties and responsibilities include: site administration, management and maintenance of existing facilities and operations; general engineering support; management and coordination of environmental investigations; generation of final reclamation plans, contracts and bid documents, conduct some of the reclamation activity, and construction supervision and management.

### **3.12.2 Seepage Capture and Treatment**

Seepage collection systems constructed under the terms of the Consent Decree are located in Ruby Gulch, Alder Spur and Carter Gulch at the Zortman Mine; and in Mill Gulch, Sullivan Creek, upper and lower Montana Gulch at the Landusky Mine. These systems intercept potentially contaminated seepage from waste rock dumps and other mine facilities. The seepage is pumped to the treatment plants for processing and discharge. These systems operate year round, with varying flow volume dependent on seasonal changes and rainfall. Money for the continued operation of these systems comes from the water treatment operation and maintenance bond. Operating costs for 2000 averaged \$80,300 per month. Total expenditures for the operation and maintenance of the seepage capture systems through December 2000 have been approximately \$1.7 million.

### **3.12.3 Leach Pad Solution Management**

As of November 11, 2001, there are 88.56 million gallons of residual leach pad process solution within the leach pads (81.65 million) and ponds (6.91 million). This leachate is discharged via the LAD system located in the Goslin Flats area during the summer months. The majority of this water is stored in the L87/89 leach pad. A biological treatment system is currently under construction to treat this water more cost effectively. Each year rain and snowfall add to the total water in the system, and depending on the ability to discharge water over the course of the year via one of the approved discharge systems, the yearly precipitation ultimately determines the amount of water that is either stored or discharged. Capping of the leach pads would reduce but not eliminate water from entering the system, so treatment of the leach pad water needs to continue. Funding for the management and treatment of leach pad waters comes from the surface reclamation bonds. Operating costs for this treatment averaged \$80,000 per month in 2000. Total expenditures since the agencies assumed management of the site through December 2000 have been approximately \$2.5 million

#### **3.12.4 Interim Surface Reclamation**

Beginning in the fall of 1999, the technical working group has identified interim reclamation activities. The recently completed and planned interim reclamation activities at the Zortman Mine will cost approximately \$3.5 million, with the money coming from the Zortman Mine reclamation bond.

At the Landusky Mine interim reclamation work occurred mostly during 2000 and continued into 2001. Costs through December 2000 for this interim reclamation have been approximately \$3.3 million and were paid for by the Landusky Mine reclamation bond.

#### **3.12.5 Final Reclamation Plan Development Costs**

Since 1999, the technical working group has been investigating reclamation alternatives. The group has collected additional data concerning site geochemistry, reclamation cap performance, revegetation needs, water balance, reclamation costs, prepared the Multiple Accounts Analysis of the reclamation alternatives, and prepared the Draft SEIS. This work was done with the specific aim of using the results to determine the final reclamation plan. Consultants have been retained to assist in this effort and additional field work was required to collect data. Expenditures associated with these efforts have totaled approximately \$1 million through December 2000.

#### **3.12.6 Restrictions on the Use of Existing Reclamation Bonds**

##### **Surface Reclamation Bonds**

The bonds for surface reclamation must be used for reclamation activities at the respective mines. The Landusky Mine reclamation bond is restricted to costs incurred at the Landusky Mine and may not be used at the Zortman Mine. The same conditions apply to the Zortman Mine reclamation bond. In addition, the State of Montana, as holder of the bonds, did not receive the face value of the bonds as a lump sum settlement at the conclusion of bankruptcy. The bankruptcy agreement states that upon the award of a competitively bid contract for surface reclamation, the sureties underwriting the bonds would release \$1.5 million each from each mine's bond. After this initial \$3 million release, the sureties are to be invoiced for payment of reclamation bills for the balance of the reclamation bond monies. To date, the agencies have been invoicing the sureties for costs incurred associated with interim reclamation.

##### **Consent Decree Construction Bond**

This bond is to be used on Consent Decree-related actions and is limited to specified line item amounts associated with specific tasks. These cover the construction of seepage capture systems in designated drainages and monies currently being used for the construction of a biological treatment system for process water containing elevated levels of nitrate and cyanide.

## **Water Treatment Operation and Maintenance Through 2017**

This bond is limited to \$731,321 per year (not adjusted for inflation) through the year 2017 for the operation and maintenance of the water treatment plants only. Funds are deposited with the State of Montana on January 1 of each year. Expenditures may not exceed specified line item estimates. Even though the agencies receive the full \$731,321 at the beginning of the year, expenditure of this money is bound by specified line items in the agency cost estimate. The agencies may not spend more than what has been estimated for the identified line item, and conversely any surplus from a line item cost may not be carried over to other line items where a deficiency may exist.

## **Long-Term Water Treatment Trust Fund**

This fund is used for the long-term (after 2017) operation and maintenance of the water treatment systems. The interest generated by the fund will be used for this purpose beginning in 2017. There are no restrictions on the use of this fund. It is financed by U.S. Treasury zero-coupon bonds that have a value of \$12.3 million upon maturation in 2017. This fund is currently \$1 million short of being fully vested to meet the projected \$15 million that was calculated in 1996 as necessary to be in the fund in 2017.

## **Zortman and Landusky Settlement Fund**

The \$1,050,000 awarded to the agencies from the bankruptcy estate was divided into two parts: \$600,000 to be used at either mine; and \$450,000 to be spent only on reclamation activities at the Zortman Mine. This fund has been used for interim reclamation at the mines and is depleted.

## **Exploration Bond**

This bond can only be used for the reclamation of exploration-related disturbances. Reclamation of these items has not been conducted to date.

## **Open Cut Bond**

This bond can only be used for the reclamation of open cut-related disturbances that are associated with the clay borrow areas.

### **3.12.7 Bond Restrictions and Their Potential Influence on Reclamation**

The restrictions placed on how and where bond monies are spent may have some bearing on the choice of reclamation plans. Water quality is perhaps one of the more significant long-term reclamation issues outstanding at the site. In order to preserve water quality, two fundamental approaches are evident: (1) prevent water from coming into contact with deleterious materials that may degrade its quality; or (2) assume all water will need to be treated prior to discharge. The former would require a barrier cover over

the waste rock dumps, pits and leach pads to prevent water from coming into contact with acidic rock, while the latter would require a system to collect and treat virtually all water on site. It is technically impracticable to construct a barrier cover system that eliminates 100% of infiltration; therefore, some level of water treatment will continue to be required in the foreseeable future.

Existing water treatment costs currently exceed the annual surety limit of \$731,321 that is available over the next 17 years. However, projections concerning anticipated future volumes requiring treatment and the quality of the water to be treated, even with a modest reclamation cover, suggest that the current level of funding may be sufficient to cover the annual treatment cost in time, especially if modifications to treatment plant design and water management can be implemented. The surface reclamation bonds, while restricted to a specific mine site, have no limitations on how the money can be spent. Conceivably, funds from the surface reclamation bond could be directed to modifying the water treatment plants to minimize annual operating costs.